EULOGY.

Mr. President,

and Gentlemen of the American Academy,

The occasion, on which we are now assembled, is one of deep but melancholy interest. We meet to do honor to the memory of an eminent fellow-citizen and academic associate, who has recently closed a most useful life; which was filled up with faithfully discharging all the duties, even the most humble, that belonged to him as a member of the community immediately around him, while his leisure hours were employed in the highest department of science, in making those great acquisitions which have shed an unfading lustre on his country among distant nations.

It is painful to realize,—indeed, who among us can feel it to be a reality?—that, but a few weeks have gone by, since our illustrious President occupied that seat, as the head of our association, in the full exercise of those intellectual and moral powers, whose constant action, though not always observed, was yet felt through every circle of society in which he moved. How saddening is the reflection, that those rare endowments now lie prostrate and powerless! that the funeral rites, not long since conducted in that simple and unostentatious manner, which was in harmony with his whole life, have separated us from him for ever!

The death of this distinguished man has been felt by all his countrymen; and the event was no sooner known, than a spon-

taneous burst of sorrow throughout the nation proclaimed the sincerest homage to his great attainments in science and his unsullied private worth.

By the Members of this Academy, with whose interests he had been so long connected, the loss is severely felt; and your earnest desire to exhibit to the public, as distinctly as was known to yourselves, that part of his character particularly, which was not so obvious to general observers, — I mean his scientific attainments, — has led you to adopt this public mode of honoring the memory of our departed associate, and to assign to me the arduous, though honorable task of discharging this last sad office. If, however, I had been permitted to consult my own feelings, it would have been my wish, that you should have selected for this duty some member of our association whose studies and pursuits were more closely allied, than my own, to those of the eminent man, whose rare attainments are to form the principal subject of the present occasion.

I am well aware of the motives, which had an influence in directing your choice; but, if my long personal intimacy with our late colleague, and my residence for many years in his native town, have afforded me personally some peculiar advantages over most of the members of our association, yet these advantages, I fear, will be outweighed by others, to which I can make no pretensions in comparison with some whom I see now before me. But your decision has been made; and, whatever may be my own judgment and feelings in the case, I yield to your opinion, and will now proceed to the discharge of the duty which you have assigned to me.

The lives of great and good men, it has often been observed, should never cease to be held up as examples, especially to the young; whose minds, as the great philosophical statesman of England has justly said, should be formed "to that docility and modesty,

which are the grace and charm of youth," and "to an admiration of famous examples."* And the public testimonials of gratitude with which we honor the memory of the dead, who have enlarged or adorned the edifice of human knowledge, are proper, in order to excite a useful emulation among the living who follow in their steps; while the glory of our country is also advanced by these very testimonials of its gratitude towards those of its children, who have shed lustre upon it.† In these respects the life of our departed associate is full of instruction, and is an example to be kept in remembrance.

The biographical details of his history have been already so fully and minutely exhibited to the public, that it is hardly necessary to ask your further attention to them.‡ Yet as this memorial of him, imperfect as it may be, would be still more incomplete without an allusion to some of them, you will expect me to advert to a few circumstances of his life, with which many of you may be already acquainted. Indeed, I cannot persuade myself, that you will in this instance feel any impatience in listening more than once to various particulars, which in most other cases you might think superfluous.

Dr. Bowditch was born at Salem, in Massachusetts, on the 26th day of March, 1773. That place had always been distinguished for its nautical enterprise; and his father and ancestors, in several generations, were by profession shipmasters.

It is now a subject of regret, that not many particulars of his earliest years have been preserved. The few surviving witnesses,

* Burke's Letter to a Member of the National Assembly.

† Notice historique sur la Vie et les Ouvrages de M. Visconti, par M. Dacier; Mém. de l' Acad. des Inscript., Tom. VIII.

‡ See the Rev. Mr. Young's Discourse on the Life and Character of the Hon. Nathaniel Bowditch, LL. D., F. R. S.; Hon. Judge White's Eulogy; and Obituary Notices in the public Journals.

however, who then knew him, concur in the general remark, that even in childhood he exhibited indications of a superior mind; that he was passionately fond of study, and had an uncommon power of intense application, with great rapidity in acquiring knowledge, particularly in his favorite science of mathematics, by which he first rose into public notice. In relation to this last point it has been stated to me by a friend as a fact, derived originally from Dr. Bowditch himself, that, while he was at school, his instructer gave him an arithmetical exercise of some difficulty for a boy of his tender years, and that he accomplished it so much sooner than was expected, that he was immediately accused of having obtained assistance in the performance of his task; and, when he denied having had any aid whatever, and resolutely persevered in asserting that he had done it wholly himself, the instructer would not believe he spoke the truth, but gave him a severe chastisement for attempting to deceive him, as he thought, by a falsehood, — an act of injustice, which was never forgotten. It is also related of him, that when he first heard of the science of Algebra, which was described to him by his brother, as a new method, practised by an instructer in the town, of solving questions by letters of the alphabet instead of the common figures, his curiosity became highly excited; and, when he had obtained the use of a book on that science belonging to the instructer, his mind became so intently fixed on the subject, — then wholly new to him, — that during the first night after the work was in his possession, as he said himself, he did not close his eyes.*

At a very early period of his life, too, that strong moral sense, which was conspicuous in his character, displayed itself, and was earnestly cherished by the affection and instructions of a fond mother, who, as he used himself to say, "idolized him."

* Rev. Mr. Young's Discourse, p. 60.

The early education of Dr. Bowditch was extremely limited; he had no other advantages of instruction, than such as could be found in the common schools, whether public or private, of that day; which were inadequate to the proper developement and discipline of the mind, and in which the inefficiency of the instructers was equalled only by the scarcely discernible acquisitions of the pupils.

After leaving school, which was at the very early age of ten years, he passed some time in the workshop of his father, who, at the close of the Revolutionary war, had been compelled by the circumstances of that trying period to resume his original occupation, which was that of a cooper. At the age of twelve or thirteen years, he was placed as an apprentice, or clerk, in a ship-chandler's shop in his native town. While in that situation, he used to devote his leisure moments to study, particularly in his favorite science of mathematics; and sometimes employed himself in little philosophical and mechanical experiments, which were interesting to himself and the boys of his acquaintance. It is also stated, that at the age of fifteen he made an almanac, complete in all its parts.*

He remained as an apprentice until he became of age; when it was decided that he should prepare himself for a nautical life; which he entered upon in his twenty-second year, in the capacity of captain's clerk, though nominally as second mate of the ship. He made five voyages (four of them to the East Indies), which occupied nine years of his life; and on some of them he went as master, though without pretending to be practically familiar with seamanship. During these voyages, numerous occasions occurred of making known, in foreign countries, his extraordinary mathematical powers; to the astonishment of all who were witnesses of the rapidity of his calculations and the accuracy of his results.

* Judge White's Eulogy, p. 16.

But a more important consequence of his mathematical knowledge, and of his example and personal influence, was, that he infused into the officers and mariners an ardent desire to make themselves masters of the principles as well as the practice of navigation; and, so intense was their thirst for this kind of knowledge, that on one of his voyages the twelve common seamen, who composed the whole crew, had acquired the method of calculating lunar observations, — at that day no small accomplishment even for the first and second officers of a ship, and one, to which a common mariner could hardly aspire.* This zeal for nautical knowledge was warmly cherished by Dr. Bowditch; he used to aid the studies of the seamen by his personal instruction and advice; and there can be no doubt, that a large portion of the nautical skill, for which his townsmen have been distinguished, may justly be traced, directly or indirectly, to him, as its original source.

At this period of his life he had acquired some knowledge of the French, Spanish, and Italian languages; and several years afterwards he added to these the study of the German, which at that time was very rare among the men of science in our country.

During one of his voyages he began his revision of the well-known work on the art of navigation, called "*The Practical Navigator*," which had then for a considerable time been in general use among persons of the nautical profession. This book, compiled originally by a British writer, John Hamilton Moore, was the most useful manual then extant on the subject. Dr. Bowditch was led to make an examination of the work, which he found to be over-

* For this fact, and the astonishment manifested in various foreign countries at his extraordinary powers of calculation, I am indebted to Captain Henry Prince of Salem, the intelligent commander with whom Dr. Bowditch made most of his voyages.

run with errors; and, at the instance of an enterprising bookseller, he began to revise it. Two revised editions were issued, but still under the name of the original compiler. In his subsequent revisions, however, Dr. Bowditch found it necessary to introduce so many improvements, and to give it so much the character of a new work, that he felt warranted in announcing it afterwards under his own name. As this was the first work published by him, and has been so extensively useful, — having in this country taken the place of every other work on navigation, — I may be allowed to mention some particulars connected with it.

The British work in its original state was a compilation, made up partly from Robertson's "Elements of Navigation," and partly from the well-known "Requisite Tables" of Dr. Maskelyne, formerly Astronomer Royal in the Observatory at Greenwich. It was constructed on a plan to contain such matter only as should be practically useful to navigators; and with that view Moore copied most of the rules of Robertson and the Tables of Maskelyne. This work, being of a moderate size and price, became popular in England and America; and in the former country had passed through thirteen editions at the time when Dr. Bowditch undertook his first revision of it; the publication of which was begun in the year 1798. In that edition none but the most material errors were the objects of revision; but various useful *additions* were made in different parts of the work.†

The popularity of the original work, as Dr. Bowditch observes, arose rather from the principle of its construction than from its execution, which was extremely faulty; for Moore, besides omitting to correct the errors of the works from which he made his compilation, added many blunders of his own; and, among them,

† Note A, at the end.

one that proved fatal to several vessels; in the Tables of the Sun's Declination, the year 1800 was set down by him as a *leap* year, which made an error of twenty-three miles in some of the numbers; and this was the cause of several vessels being wholly lost, and of others being brought into great danger. Dr. Bowditch justly characterizes this as "a very criminal inattention" in the compiler of a work, upon whose accuracy the lives and safety of thousands of navigators depended.*

In the year 1802 Dr. Bowditch published the "Practical Navigator" under his own name; this edition was originally to have been the *third* American one of Moore's work. But, as Dr. Bowditch observes in his Preface to it, on a careful examination, it was found so erroneous in the Tables, and so faulty in the arrangement, that he "concluded to take up the subject anew," and, without being confined to Moore's work, to have recourse to those authors, whose writings would afford the best materials for the purpose; to introduce additions and improvements, and to ensure accuracy in the Tables by *actually going through all the calculations* necessary to a complete examination of them.†

Notwithstanding the minute attention thus bestowed upon all the details of this work, Dr. Bowditch modestly says; "The author had once flattered himself that the Tables of this collection which did not depend on observations would be *absolutely correct;* but in the course of his calculations he has accidentally discovered several errors in two of the most correct works of the kind extant, viz. Taylor's and Hutton's Logarithms, notwithstanding the great care taken by those able mathematicians in examining and correcting them; he, therefore, does not absolutely assert, that these Tables are entirely correct, but feels conscious, that no pains have been spared to make them so."

* Preface to the Practical Navigator. † Note B, at the end.

What a contrast does this language form with that of the original compiler; who, in the very edition which contained the egregious and "criminal" blunder before mentioned, as well as his other "eight thousand" errors, has the assurance to announce to all "mariners," that "he sells no *sea-books*, charts or instruments but such as *may be depended on;* consequently he excludes all those old, *inaccurate*, and erroneous publications, the depending upon which *has often proved fatal to shipping and seamen.*"

Notwithstanding this boasting language, however, as soon as Dr. Bowditch's revision was known, the usual orders, which had before annually gone from America to England for thousands of copies of Moore's Navigator, were stopped at once; the American work came into general use immediately in our own country, and was republished in London.*

Useful, however, as the "Practical Navigator" has been, it is not thus particularly noticed, as a work to which Dr. Bowditch himself attached any importance in respect to his scientific reputation, or in any other view than as a *practical manual;* the first excellence of which is, the greatest possible accuracy. From the period of its original publication, therefore, he spared no labor in making the most minute corrections and improvements. In the last edition, published in the autumn of 1837, the body of Tables has been increased, from thirty-three to fifty-six; some of them being entirely new, and others essentially improved or corrected. One or two of these improvements may be here referred to, as showing the extreme care used in the construction of the work. The tenth Table contains the distances at which any object is visible at sea, calculated by the rule given in Vince's Astronomy

* See Note C, at the end.

(§ 197), in which the *terrestrial* refraction is noticed, while this was neglected by Robertson, Moore, and others, and of course their tables are defective. His thirteenth Table contains the Dip of the horizon for various heights, calculated also by the rule in Vince's Astronomy (§ 197), in which the *terrestrial* refraction is likewise allowed for. In this Table all the numbers differ a little from those published by Dr. Maskelyne, who had made a different allowance for that refraction.*

I ought to add here, that Dr. Bowditch was enabled to give the greater accuracy to his work by means of a collection of Manuscript *Journals* of his seafaring townsmen, preserved in the valuable Museum of the East India Marine Society in Salem. By a regulation of that Society, which it is believed was proposed by Dr. Bowditch himself, each member, when going upon a voyage, is furnished with a blank book, uniformly ruled and prepared for the purpose of keeping a *journal* of nautical and other observations and remarkable occurrences; on the termination of the voyage each journal is deposited in the Museum of the Society; and the whole collection of them, now amounting to many volumes, forms a repository of innumerable facts, in nautical and geographical science, not to be found in any other sources.

In connexion with this subject I may here add, that he employed himself during three successive seasons, 1805, 1806, and 1807, with two intelligent assistants, in making a thorough hydrographical survey of the harbours of Salem and three neighbouring towns; of which he published a well-known chart, of surpassing beauty and accuracy. With such extraordinary precision was this laborious work accomplished, that the pilots of the port discovered, and were the first to observe to the author, that their established

* See Note D, at the end.

landmarks (which, however, Dr. Bowditch did not know to be such) were in fact laid down with such perfect accuracy in his survey, that the different ranges and bearings on the chart corresponded, with the utmost exactness, to those of the natural objects themselves.

At an early age the attention of Dr. Bowditch was directed to the *Principia* of his great master, Newton. But, as that work was published in the Latin language, which he had not then learned, he was obliged to begin the reading of it by asking the assistance of some college students of his acquaintance; who, during their vacations, used to render him such aid as they were able, in occasionally translating for him. He soon found, however, that the acquaintance, which those young persons had with the classical Latin of Cicero and Virgil, was of little comparative value in enabling them to comprehend the modern and technical Latin of Newton's work; and that his own knowledge of the subjects discussed by Newton, with the aid of the mathematical processes and diagrams on the pages of the Principia, would, with a little study of the language, qualify him to read that and other scientific works written in Latin, without the assistance of his youthful and inexperienced interpreters. He accordingly began to study that language himself, just before he entered upon the seventeenth year of his age. It is stated, that the first Latin book which he undertook to read was *Euclid's Geometry;* but the great subject of his studies in that language was the *Principia.**

In the earlier period of his mathematical studies, his pecuniary means were very limited, and he was unable to buy any books of science. But, by the liberality of a few individuals in his native town, who took a warm interest in the encouragement of his talents

* See Note E, at the end.

and pursuits, he had access to a small but valuable library (owned by an association of scientific and literary gentlemen), which contained a copy of the *Philosophical Transactions* of the Royal Society of London. This work was a treasure to him; and he began, in his eighteenth year, to make copious abstracts of all the mathematical papers in that immense repository of science. This labor was continued through many years; and the heavy folio volumes of those manuscript abstracts still remain in his library, the testimonials of his untiring zeal and industry.

In the year 1806, at the particular instance, as it is understood, of the late Chief Justice Parsons, (whose extraordinary attainments included a knowledge of some of the higher branches of mathematics,) Dr. Bowditch was elected Professor of Mathematics and Natural Philosophy in the University at Cambridge. He could not, however, be persuaded to accept that professorship; but preferred remaining in his native town, discharging the duties of the office which he then held (of President of a Marine Insurance Company), and pursuing his studies at such leisure hours as his official business would permit. Subsequently, however (in 1826), he became a member of the *Corporation* of the University, and remained in that body till his death.

Upon the establishment of that important institution, the Massachusetts Hospital Life Insurance Company, at Boston, in the year 1823, his peculiar talents were deemed indispensable to its organization and management; and he was accordingly invited to take charge of it under the title of its Actuary. The great exactness of calculation, and the order and precision, introduced by him, will long attest the comprehensiveness of his views, and his practical skill in conducting the affairs of that association.

On the occasion of leaving his native place, to enter upon this new office, his townsmen gave him a public dinner in testi-

mony of their respect for his private character, as well as of the public services rendered by him to the cause of science.

He was elected a member of the American Academy in the year 1799; and from that period he communicated several papers, upon various questions of science, which are published in the different volumes of the Academy's Memoirs, and of which it is proper to give some account.

His first communication was "A new Method of working a Lunar Observation," published in the second volume of the Memoirs. This had been used by him for a long time before its publication, and previously to the appearance of the Transactions of the Royal Society for 1797, in which there is a method somewhat similar, by Mr. Mendoza y Rios. His object was, to simplify the modes of applying the *Corrections*, as they are called; which was always an embarrassing process to learners. By Dr. Bowditch's method there remained no difference of cases, and the Corrections were always to be applied in the same manner, whatever might be the distance and altitudes of the observed bodies. In an *Appendix* to this useful paper he proposes an improvement, to abridge materially the labor of making the necessary calculations for determining the longitude. This method was afterwards incorporated (with further improvements) into his Practical Navigator, where it has ever since retained its place. It may be here added, that the importance of this method, in a practical view, was so highly estimated abroad, that the eminent French astronomer, M. Delambre, thought it deserving of particular notice and commendation in the *Connoissance des Tems* (for 1808), published under his care, while a member of the French Board of Longitude.

The next paper communicated by Dr. Bowditch to the Academy was upon a question of a higher class, and is entitled "Observations of the Comet of 1807." Before any account of this comet had

reached America, Dr. Bowditch had published, in one of our journals, a statement of the elements of it; and he came to the conclusion (which was afterwards found to be correct), that the comet in question was one which was before unknown to astronomers.* I allude to this circumstance, not by way of proving that he had displayed what he would himself have considered as evidence of mathematical powers, but as one, among numerous instances, to show, that results then obtained by him, as well as by eminent foreign astronomers, might be safely relied upon.

In the same volume of the Memoirs is his valuable paper containing "Observations on the remarkable Total Eclipse of the Sun, which happened on the 16th of June, 1806." This is the more interesting, as it contains, in the modest form of a *Note*, the first public mention made by him of an error in La Place's *Mécanique Céleste*, in the estimate of the oblateness of the earth. Dr. Bowditch, in determining the latitude of his place of observation, assumed the difference between the equatorial and polar diameters of the earth to be $\frac{1}{300}$th; which, he adds, is conformable to the Tables of La Lande; but La Place, from the observed length of pendulums, had calculated the ellipticity at $\frac{1}{336}$th; in which, Dr. Bowditch observes, a small mistake was made in one of the equations, which, if corrected, would make the result, that La Place should have given on his own principles, $\frac{1}{315}$th; which does not differ much from $\frac{1}{305}$th, the result deduced by La Place himself from the lunar theory.†

The next memoir by Dr. Bowditch was one of great practical value; an "Application of Napier's Rules for solving the Cases of Right-angled Spheric Trigonometry to several Cases of Oblique-angled Spheric Trigonometry"; in which, by a small alteration in the expression of those rules, they are made to include the solu-

* Mem. Amer. Acad. Vol. III. p. 1.

† Ibid. p. 18.

tions of most of the cases of oblique-angled spheric trigonometry in a more simple manner than in their original form.

Another interesting communication by him is upon the extraordinary aërolite, or meteor, that exploded over the town of Weston in Connecticut, on the 14th of December, 1807; which excited greater attention throughout this country than any phenomenon of the kind had before done. The object of Dr. Bowditch was, to make an estimate, as nearly as practicable in such a case, of the height, direction, velocity, and magnitude of the body in question. He was induced to collect all the observations made, and to go into the calculations he has given, because, as he states, the methods of making these calculations are not fully explained in any treatise of trigonometry common in this country; and because one of his problems is not, to his knowledge, given in any treatise of spherics.

In this curious and interesting paper his friendship has led him to make acknowledgments to me personally, which I do not feel conscious of deserving, for some supposed assistance rendered him in collecting and combining the observations there detailed. The results obtained by him in the case will not be uninteresting.

The course of the meteor was in a direction parallel to the surface of the earth, and at the height of about *eighteen* miles. These points, he thinks, were ascertained with a considerable degree of accuracy. From satisfactory data the height must have exceeded *thirteen* miles. Its velocity probably exceeded *three miles* in a second, which is fourteen times as great as that of sound, and nearly as great as that of a satellite revolving about the earth at the same distance. The *magnitude* of the meteor was a subject of more difficulty; as the apparent diameter was not measured exactly by any observer. The least of all the limits of the diameter was 491 feet; which would give a cubic bulk of *six millions of tons.* But, as the whole mass which fell at Weston did not exceed half a ton, and would not

make a spherical body that would have been easily visible at the distance of several of the places of observation, there seem to be some grounds for the opinion, that by far the greater part of the mass continued on its course without falling to the earth.

In the year 1811 a remarkable comet made its appearance, and was the subject of another able memoir by Dr. Bowditch; the result of which was, that this, like the comet observed by him in 1807, was one that had been before unknown to astronomers.* The calculations in this case were made with vast labor and perseverance, most of which would have been spared, as he himself used to observe, if the improved methods of the present day had then been known in this country.†

Another valuable paper of Dr. Bowditch was published in the same volume on that important subject, the Variation of the Magnetic Needle; containing an account of a series of observations made by himself in the years 1805, 1808, 1810, and 1811.

It had been asserted in some publications of that period, that the variation had ceased to decrease, and was then rapidly increasing. This was stated, particularly in New York, by persons, who, from their official situations as public surveyors, were supposed to be the most competent judges; and observations and facts were adduced to prove, that this change had taken place between the years 1804 and 1807. It was said, that the boundary lines of certain towns in that State, and the course of a particular turnpike road, had differed, in the space of four or five years, between 15′ and 45′ from the original surveys; and hence it was inferred, that a material change in the variation had actually taken place.

But Dr. Bowditch remarked, that the facts, as stated, by no means warranted the conclusion drawn from them; for, in the observations

* Mem. Amer. Acad. Vol. III. p. 313. † See Note F, at the end.

made, no notice was taken of the *daily* variation of the needle, which sometimes exceeds any of the changes that had been observed in New York; besides which, the variation found at the same place with different instruments will frequently vary half a degree; and by changing the place of an instrument, only a few feet, the same effect will sometimes be produced.

As this subject was of importance in a country like ours, where the boundary lines of towns and tracts of land are determined by the compass, and was of still greater consequence in our navigation, Dr. Bowditch instituted a course of observations in the four different years above mentioned. These observations were conducted with great care, and a minute attention to all those accidental causes, which might produce irregularities in the needle. And, to show the necessity of the utmost caution in such a case, it will be sufficient to state, that on one day, when he was observing with two excellent theodolites standing in the same place, the variation differed above *fifty* minutes; which was greater than any of the changes observed in New York, that had given rise to the discussions of the subject.

Dr. Bowditch came to the conclusion, that the differences noticed in New York arose in a great degree from the shortness of the needles used by the observers, and, perhaps, in part from the imperfection of their instruments. To obviate these difficulties, he procured a needle of twenty-four inches in length, suspended on an agate, and mounted with great care in every particular. This instrument was generally used in one of the rooms of his house; but, in order to ascertain whether the building affected the needle, he fixed a true meridian line on a table in the garden adjoining his house and at the distance of thirty feet from any building; and he found, that, even in so short a distance between the two places of observation, the variation in the garden was less by 3′ 25″ than in

the house; and this correction he applied to all his observations.

I have given these particulars for the purpose of showing, with how much care he proceeded in his investigations, and how cautious we should always be, in admitting unqualified statements on questions of science which require delicate and accurate experiments, and thus hastily proceeding to account for a supposed phenomenon, before we have ascertained the fact of its existence.

But, in order to give a more complete view of the labor of conducting such a course of experiments, I ought also to state, that during those four years Dr. Bowditch made no less than five thousand one hundred and twenty-five observations; the result of all which was, that the needle had not then experienced any change of variation in this part of the country, but continued to approach the true meridian with nearly the same velocity as at the time of the earliest observations on record; that is, nearly about 1′ 19″ a year.*

This interesting and valuable paper was followed by one relating to a subject, which can hardly be made intelligible without a more minute explanation than can be given in this place, — *the Motion of a Pendulum suspended from two Points.* The experiment was first suggested and made by Professor Dean of Vermont, to illustrate the apparent motion of the earth as viewed from the moon. Dr. Bowditch was much interested in this experiment; and he undertook to examine the theory of the motions of a pendulum suspended in that manner. The singularly curious and interesting results of his investigation are contained in the paper here referred to.†

His next communication to the Academy was on an important mistake which existed for half a century in the Solar Tables of Mayer, La Lande, and Zach. And on this subject it should be

* Mem. Amer. Acad. Vol. III. p. 337. See Note G, at the end.

† Mem. Amer. Acad. Vol. III. p. 241.

observed, according to Dr. Bowditch, that in the Solar Tables of Delambre, published in 1806, the form of the Table is wholly altered; the method of entry by a double argument being used; and thus by taking a different path the error is avoided without noticing that it really does exist in the other works.*

This paper was followed by an elaborate one upon the oblateness of the earth; which was suggested by some errors contained in the article "Earth," published in "Rees's Cyclopædia." Dr. Bowditch was induced to notice the article in question, because that popular work had an extensive circulation in this country, and it was desirable that "currency should not be given to inaccurate ideas on the subject."†

His next paper is only a demonstration of the practical method (given in his Navigator) of correcting the apparent distance of the moon from the sun, or a star for the effects of parallax and refraction. The advantage of his rule is, that all the corrections are *additive*, which renders it peculiarly adapted to the daily use of mariners.

This was followed by a communication upon an improved formula, by himself, for computing the Dip of the Magnetic Needle in different latitudes, according to the theory of the French mathematician, Biot.

His next communication was on the methods of correcting the elements of the orbit of a Comet, in Newton's Principia and La Place's Mécanique Céleste. This was first published in the fourth volume of the Academy's Memoirs; but the substance of it had been communicated several years before to the late Rev. Dr. Willard, then president of the University, and one of the best practical astronomers of that period. Some importance is justly attached to this paper, as it relates to methods originally adopted by Newton

* Mem. Amer. Acad. Vol. IV. p. 28. † Ibid. p. 30.

himself (though now not much used), and sanctioned by his commentators.

The immediate occasion of examining this subject, was an attempt made by a celebrated English mathematician, the late Mr. Emerson (in the notes to a new edition of La Motte's Translation of the Principia), to prove the accuracy of two equations used in the case; this had also been before attempted by other commentators on the Principia, as Gregory, Le Seur, and Jacquier; "and in none of the editions (that Dr. Bowditch had seen), not even that published by Bishop Horsley, is any doubt of their accuracy expressed or even insinuated." Yet, the method sanctioned by these high authorities, would, as Dr. Bowditch states, always make the corrections in question "double of what they ought to be." The method of La Place, which is also examined by Dr. Bowditch, though simple and elegant when used with *a small* number of observations, becomes objectionable and inconvenient when the number of observations is large.*

In the same volume we have a concise but interesting paper on the great question of the permanency of the Solar System, which I shall notice more particularly hereafter.

This was followed by an important paper on Doctor Matthew Stewart's formula for computing the motion of the Moon's apsides. It presents a curious case, in astronomical science, where a formula, apparently *general*, happened to be true only in the *particular* instance in which it was accidentally first used by its author.

In the year 1763 Dr. Matthew Stewart, of Edinburgh, published his computation of the Sun's distance from the earth by means of the motion of the Moon's apsides; and four years afterwards Bishop Horsley made a communication to the Royal Society of London in

* Mem. Amer. Acad. Vol. IV. p. 62.

support of the accuracy of that calculation. Some time after that, however, two British mathematicians, Mr. Dawson and Mr. Landen, took the opposite side; the latter of those writers showing, that "several small quantities neglected by Dr. Stewart, in order to simplify the *geometrical* investigation, would produce a very great effect on his estimate of the Sun's distance." Mr. Landen also expressed some *doubts* of the accuracy of Dr. Stewart's principles; but he made no calculation to ascertain, whether the neglected force did in fact produce any effect in the result.

This subject was again brought forward in the interesting biography of Dr. Stewart by Professor Playfair;* who, indeed, notices the objections of Mr. Landen, but concludes, notwithstanding, that Stewart's method, "instead of being liable to objection, is deserving of the highest praise, since it resolves, by *geometry alone*, a problem which had eluded the efforts of some of the greatest mathematicians, even when they availed themselves of the utmost resources of the integral calculus."

It is a remarkable fact in the history of astronomical science, that the accuracy of Stewart's method should also have been maintained by Dr. Hutton, by La Lande, and, still more recently, by Professor Playfair, in his elegant article on Physical Astronomy, re-published so lately as the year 1824, in the Supplement to the Encyclopædia Britannica, (in which Dr. Stewart is said to have *demonstrated* this remarkable theorem,) and again by the same writer, in an able article of a celebrated Review, in which he says, that Dr. Stewart had treated this subject "with singular skill and success."†

* Transactions of the Royal Society of Edinburgh, Vol. I. p. 69, of the Historical part.

† Edinburgh Review, Vol. XI. p. 280.

After noticing these historical facts in regard to the question, Dr. Bowditch remarks, that these late opinions of eminent mathematicians do not remove the objections which had been raised; that is, that the neglect of the tangential force and other peculiarities of the method might possibly affect the result; and he then proceeds to the examination of the question, whether this fundamental theorem expresses, in an approximative form, the mean motion of the apsides, supposing, with the author, the eccentricity to be very small, or the orbit nearly circular. He observes, at once, in his communication, which was written twenty years ago, that there is now no difficulty in settling this point by means of the analytical expression of the motion of the apsides given by La Place; and, upon applying that method, he found that Dr. Stewart's formula was far from being so correct as had been supposed by the able writers above referred to, but, on the contrary, that it was essentially defective. The first and most important term of the series is *double* its true value; and the whole formula will not give an accurate numerical result, except when the primary planet and satellite have a certain proportion to each other; and this, by a remarkable coincidence, happens to be the case nearly with the earth and Moon, the example taken by Dr. Stewart; but the same formula would not answer, if the Moon's distance from the earth were much greater or much less than it now is; and it would require but a very small decrease of the Moon's mean distance from the earth, to render the Sun's distance infinite when computed according to Doctor Stewart's directions; so that this method would have failed, if it had been applied to other cases, as, for instance, Jupiter's satellites; and he then demonstrates, that such would be the result.

Dr. Bowditch concludes, that the defect in the most important theorem of Dr. Stewart makes *his method wholly fail.* He attributes the mistake in this case entirely to the use of the *geomet-*

rical method of investigation; he observes, that the failure of so distinguished a mathematician shows, how extremely difficult it is to apply this method with success to complicated problems requiring great accuracy; and that there are few questions in the higher branches of Physical Astronomy, where the ancient geometry can be used with much advantage.*

I find but three other communications of Dr. Bowditch to the Academy, — the first, on the meteor which passed over Wilmington in the State of Delaware, November 21st, 1819;† the second, upon a mistake found in the calculation of M. Poisson relative to the distribution of the electrical matter upon the surfaces of two globes;‡ and the third, upon the elements of the Comet of 1819.§

Such is a brief account of the occasional labors of Dr. Bowditch in the cause of science during those leisure hours only, which an active life afforded him. Of themselves they would be deemed not inconsiderable for any individual, who was so circumstanced as not to be able to make the objects of science his exclusive pursuit; and, if we would justly estimate the labors of our countrymen, in comparing them with those of the favored individuals in the various states of Europe, who are enabled, either by the patronage of their governments or otherwise, to devote their whole lives to science, this difference of circumstances should ever be kept in view.

As to the patronage of government, which, indeed, among few nations has stimulated genius to such intense exertions as we find in the history of human knowledge, — alas! in our own country, a country of which we have just cause to be proud in numberless respects, — how little has it hitherto been able to effect for science. If our lamented President had been compelled by his pecuniary

* Mem. Amer. Acad. Vol. IV. p. 110.

† Ibid. p. 295.

‡ Ibid. p. 307.

§ Ibid. p. 317.

circumstances, or could have been induced by any motive, to depend upon the patronage of government, how long a period would have elapsed before we should have seen the publication of his great work, which has conferred such lasting honor upon his native land!

Fortunately for himself, and for the cause of science in this country, Dr. Bowditch was able (though with no small sacrifice of that property which he had desired to leave undiminished for his children,) to publish the work at his own expense. He might, indeed, have effected this by the aid of numerous friends, as well as of the American Academy; who would cheerfully have defrayed the expense, and actually offered to do it. But his high sense of personal independence could not be brought to submit to what he considered, in any degree, as a pecuniary obligation to private friends in such a case; he was willing to delay his work, and, if found necessary, even to retrench his daily expenses, moderate as they were, rather than to accept the aid offered him. In this determination he was encouraged by the noble-spirited matron, to whom he had been united in marriage for many years, and who declared herself ready to submit to any sacrifice that might be the consequence of his decision; an example worthy to be placed by the side of that, which the history of literature has recorded of the illustrious German scholar, Reiske, who would have refunded to his *six* subscribers the price of their copies, and then have abandoned in despair the publication of his great work (the Greek Orators), had not his affectionate and resolute consort, in a determined tone, said to him, "Trust in God; sell my jewels to defray the expense; what are a few shining baubles to my happiness."

Besides the publications already mentioned, Dr. Bowditch was the author of a few reviews, and other occasional articles, in some of the periodical works of this country.*

* See Note H, at the end.

But the great work, upon which his fame as a man of science will ultimately rest, is his copious and profound *Commentary* upon the *Mécanique Céleste* of La Place, of which he made the first entire translation, and which he has elucidated in a manner that commands the admiration of men of science in all countries.

To do justice to this invaluable work, would require much more time than can be allotted to it on the present occasion, even if I were qualified to perform that task in a manner worthy of the subject. The labors of Dr. Bowditch lie so far out of the range of readers, who do not make works of that kind a subject of their particular attention, that, amidst the universal and just commendation of the work, a very imperfect knowledge of its real value still exists, even among many well-informed persons. Difficult, however, as it may be for me to do justice to this part of my subject, yet the honored name of our President has been so long connected with this work of La Place, that it is necessary for me to occupy a part of your time with a few particulars in relation to the *Commentary* and the original work, — a work, which, like Newton's, in the preceding century, may justly be called the *Principia* of the age; and the author of which, by the common consent of men of science both in Great Britain and elsewhere, is placed in the next rank to his great predecessor, Newton.

We often hear the names of the original *Mécanique Céleste* and of the *Translation and Commentary* of our late president; and always accompanied with vague praises, which leave no distinct impression of the one or the other. Yet, if we would form a just estimate of the labors of Dr. Bowditch, I need not say, that it is indispensable to have a clear conception of the design and execution of both the works.

On the present occasion, if the remarks I am about to make were

to be addressed to an association exclusively devoted to physical and mathematical science, I should neither think it proper, nor should I be presumptuous enough, to enter upon a lengthened examination of works, with which persons devoted to those pursuits are already more familiar than I can myself pretend to be.

But addressing myself, as I do, to a society composed of individuals, the greater part of whom have given more of their leisure to researches in literature and general science, than to physical astronomy or other branches of mathematical investigation, I shall be pardoned for some details which might otherwise have been spared, but which, unless I greatly deceive myself, will not be destitute of interest to all who hear me.

Now, at the very commencement, and as an introduction to those details, in order that we may justly estimate the high importance of the original work of La Place, (independently of the Translation and Commentary of Dr. Bowditch,) it is necessary to go back, in the history of physical astronomy, beyond the age of the illustrious author, and for a moment direct our attention to that glorious epoch, when a flood of intellectual light burst forth from the mighty mind of Newton, and, with the splendor of the sun in the firmament, revealed to his wondering fellow-mortals the master principle of the structure and laws of the visible universe.

"Astronomy," says La Place, "is a science which above all others presents us with the longest connected series of discoveries. The distance is immense between the first transient glance of the heavens, and that extended and general view by which, at this day, we are able to embrace the past and future condition of the system of the world. In order to arrive at the latter, it was necessary to observe the heavenly bodies for many centuries; to recognise in their apparent courses the real motion of the earth; to ascend to the laws of the planetary movements, and from those laws to the principle

of universal gravitation; and finally, to descend again from that principle to a complete explanation of all the celestial phenomena, even in their most minute details. And this is what the human intellect has accomplished in Astronomy," * that science, which, in another part of his work, he justly characterizes as "the most sublime of all the natural sciences," and whose objects cannot fail to draw around it a degree of their own splendor and magnificence; while the immense masses of those objects, their boundless distances, and the inconceivable velocity, yet steadiness and regularity of their movements, while they present the highest exercise to the human mind, deeply affect the imagination and impress the beholder with some conception of that mighty energy, which sustains them in their motions with a permanency to which we can see no limit.

"It was reserved for Newton," says La Place again, "to make us acquainted with the general principle of the heavenly motions. Nature, while she endowed him with a profound genius, took care also to give him to the world at the most favorable moment. Descartes had changed the face of the mathematical sciences; Fermat had laid the foundation of the geometry of infinites; Wallis, Wren, and Huygens had just discovered the laws of motion; the discoveries of Galileo on the fall of heavy bodies, and those of Huygens on the doctrine of evolutes and centrifugal forces, led to the theory of motions in curves; Kepler had determined those which the planets describe, and had a glimpse of universal gravitation; and finally, Hook had justly perceived, that their motions were the result of an original projectile force combined with the attraction of the sun. The mechanism of the heavens, therefore, seemed only to be waiting for some man of

* Exposition du Système du Monde, p. 1.

genius, who should generalize these discoveries, and be enabled to extract from them the law of gravitation. This was what Newton accomplished, in his immortal work on the Mathematical Principles of Natural Philosophy." *

As soon as Newton had arrived at this great principle, (continues La Place,) he perceived, that the important phenomena of the system of the world flowed from it. He found, among others, the following results; that the attractive force of a solid or a hollow sphere, upon a particle of matter placed without its surface, is the same as if the whole mass were collected in its centre; he proved that the rotation of the earth must flatten it at the poles; and he determined the laws of the variation in the degrees of the meridians and of gravity, upon the hypothesis, that the earth was homogeneous; he perceived, that the action of the sun and moon upon the earth, as a spheroid, must produce an angular motion on its axis of rotation, must cause a retrogradation of the equinoxes, raise the waters of the ocean, and keep up, in that immense fluid mass, those oscillations, which we observe in it, called the ebb and flow of the tide. In fine, he satisfied himself, that the inequalities in the moon's motion were owing to the united action of the sun and earth. "But, with the exception of what relates to the elliptical movements of the planets and comets, the attraction of spherical bodies, and the intensity of the attractive force of the sun, and of planets accompanied by satellites, all these discoveries were merely sketched out, or exhibited in their first draught. His theory of the planets is limited by the supposition that they are homogeneous; his solution of the precession of the equinoxes, notwithstanding its ingenuity and the apparent agreement of its results with observations, is yet defective in many respects. Among the

* Exposition du Système du Monde, p. 414.

numerous perturbations of the motions of the heavenly bodies, he has considered only those of the motions of the moon; and the most considerable of these, the evection, escaped his investigation. He thoroughly established the existence of the principle which he had discovered; but the developement of its consequences and its advantages was the work of the successors of this great geometer. The imperfections of the calculus of infinites, in its origin, did not permit him completely to resolve the difficult problems presented by the theory of the system of the world. He was often obliged to give mere sketches, or estimates, always uncertain, till they have been verified by a rigorous analysis. Notwithstanding these unavoidable defects, however, the importance and general form of the discoveries, with numerous profound and original views, which were the germ of the most brilliant theories of the geometers of the last century, — all of which he exhibited with great elegance, — ensure to the work on the Mathematical Principles of Natural Philosophy, the preëminence over all other productions of the human intellect." *

Such was the state in which the discoveries of Newton had left the science of physical astronomy, when the great work of La Place appeared, — undoubtedly the most important one that has distinguished the present age; and conducted by an analysis so far gradually perfected beyond that of any former period, that it has been said by an able writer, that if Newton or Leibnitz should have returned to the world at any time since the middle of the last century, they would have been unable, without great study, to follow the discoveries which their disciples had made, by proceeding in the line which they themselves had pointed out.† The grand

* Exposition du Système du Monde, p. 418, &c.

† Edinburgh Review, Vol. II. p. 252; in an article by Professor Playfair.

result of the efforts of those disciples was, that, at the close of the last century, there was not one of the phenomena, which had perplexed astronomers in the motions of the heavenly bodies, that could not be explained on the principle of gravitation; and the conclusions of *theory* were reconciled with the observations, except so far as imperfections in practice will ever occasion slight deviations from theory.

The time, then, seemed to have come, as La Place himself had said of Newton, for some man of genius to reduce into one work the whole theory of astronomy, with all the discoveries in the science since the age of the great English geometer; and La Place was the man, in all Europe, whom the scientific world would have selected for so great an undertaking.*

This vast labor La Place undertook in his *Mécanique Céleste.* He says, in his brief but comprehensive Preface, "The whole of the results of gravitation, upon the equilibrium and motions of the fluid and solid bodies which compose the solar system and the similar systems existing in the immensity of space, constitute the object of *Celestial Mechanics,* or the application of the principles of mechanics to the motions and figures of the heavenly bodies. Astronomy, considered in the most general manner, is *a great problem of mechanics,* in which the elements of the motions are the arbitrary constant quantities. The solution of this problem depends, at the same time, upon the accuracy of the observations and the perfection of the analysis. It is very important to reject every empirical process, and to complete the analysis, so that it shall not be necessary to derive from observations any but indispensable data. The intention of this work is to obtain, as far as may be in my power, this interesting result."

* Edinburgh Review, Vol. II. p. 253.

All this, says Dr. Bowditch, "he has accomplished, in a manner deserving the highest praise for its symmetry and completeness; but, from the abridged manner in which the analytical calculations have been made, it has been found difficult to be understood by many persons, — who have a strong and decided taste for mathematical studies, — on account of the time and labor required to insert the intermediate steps and demonstrations, necessary to enable them easily to follow the author in his reasoning." Dr. Bowditch then adds: "To remedy, in some measure, this defect, has been the chief object of the translator in the *Notes.* It is hoped, that the facility arising from having the work in our own language, with the aid of these explanatory Notes, will render it more accessible to persons who have been unable to prepare themselves for this study, by a previous course of reading in those modern publications, which contain many important discoveries in analysis, made since the time of Newton.

"The notes were written at the time of reading the volumes, as they were successively published. The translation was made between the years 1815 and 1817, at which time the four first volumes, with the several appendices and notes, were ready for publication."*

I must now ask you to follow me a little longer, while I lay before you a few particulars in relation to the original work and the Commentary; and I persuade myself, that you will find in them a degree of interest, which many persons would not expect in works lying so far out of the range of general readers, but yet involving discussions of the highest questions on which the human mind can employ itself.

I shall first ask your attention to as short a statement as possible of the leading subjects in the original work, and then to our late President's Commentary upon it.

* Bowditch's La Place, Vol. I. Preface.

In the very commencement, you cannot fail to be struck with the broad and general views, which the author has taken of his vast subject, as a whole; and the regular and beautiful order in which he gradually proceeds to every necessary detail, till the entire subject is exhausted; thus justifying the remark made by an able writer, before quoted; who says, "Such is the work of La Place, affording an example, which is yet solitary in the history of human knowledge, *of a theory entirely complete*; one that has not only accounted for all the phenomena that were known, but that has discovered many before unknown, which *observation* has since recognised. In this theory, not only the elliptic motion of the planets, relatively to the sun, but the irregularities produced by their mutual action, whether of the primary on the primary, of the primary on the secondary, or of the secondary on one another, are all deduced from the principle of gravitation; that mysterious power, which unites the most distant regions of space, and the most remote periods of duration. To this, we must add the great truths, — brought in view and fully demonstrated, by tracing the action of the same power through all its mazes, — that all the inequalities in our system are periodical; that, by a fixed appointment in nature, they are each destined to revolve in the same order, and between the same limits; that the mean distances of the planets from the sun, and the time of their revolutions round that body, are susceptible of no change whatsoever; that our system is thus secured against natural decay; order and regularity preserved in the midst of so many disturbing causes; and anarchy and misrule eternally proscribed." *

The first principal division of the *Mécanique Céleste* treats of the "Laws of Equilibrium and Motion"; and, under that general

* Professor Playfair, in the Edinburgh Review, Vol. II. p. 277.

head, La Place considers the Equilibrium and Composition of Forces which act on a Material Point; the Motion of a Material Point; the Equilibrium of a System of Bodies; the Equilibrium of Fluids; the General Principles of the Motion of a System of Bodies; the Laws of Motion of a System of Bodies, in all the relations mathematically possible between the Force and Velocity; the Motions of a Solid Body of any Figure whatever; and the Motion of Fluids.

The investigation of these great problems, in this very general form, it will be perceived, prepares the way for the consideration of the systems of bodies, and the individual bodies composing those systems, both solid and fluid, which are the constituent parts of the universe.

La Place then proceeds to the second principal division of his work; which is, the Law of Universal Gravitation, and the Motions of the Centres of Gravity of the Heavenly Bodies; and, under this part of his subject, he considers the Law of Universal Gravity, deduced from observation; the Differential Equations of the Motion of a System of Bodies, subjected to their Mutual Attractions; the First Approximation of the Motions of the Heavenly Bodies, or Theory of the Elliptical Motion; the Determination of the Elements of the Elliptical Motion; the General Methods of finding the Motions of the Heavenly Bodies by successive Approximations; the Second Approximation of the Celestial Motions, or Theory of their Perturbations; the Secular Inequalities of the Motions of the Heavenly Bodies; and the Second Method of Approximation to the Motions of the Heavenly Bodies, which is founded on the Variations, which the Elements of the Motion, supposed to be Elliptical, suffer by means of the *periodical* and *secular* inequalities. All these profound and complicated questions, particularly the *secular* inequalities, — whose progress and effects are so extremely slow, as to have eluded the calculation of all La Place's predecessors, —

are developed by him in so exact and satisfactory a manner, as hardly to leave any thing further to be expected from the most intense application of the human mind, with the aid of the most perfect instruments of analysis.

The two divisions, or books, above mentioned, form the first volume of the entire work.

The third book, with which the next volume opens, treats of the Figures of the heavenly bodies, deduced theoretically, in the most generalized form, from the attraction of homogeneous spheroids terminated by surfaces of the second order; the developement of the attraction of any spheroid in a series; the figure of a homogeneous fluid mass in equilibrium, and having a rotatory motion; and, lastly, the figure of a spheroid, differing but little from a perfect sphere, and covered by a fluid stratum in equilibrium.

These theoretical results are then compared with actual observations made of the figures of the Earth and the planet Jupiter; of which last the very perceptible oblateness, as the author observes, has been determined with great accuracy.* This third book ends with an investigation of the Figure of the Atmosphere of the heavenly bodies.

La Place next considers the Oscillations of the Sea and the Atmosphere; discussing, in their order, the theory of the ebb and flow of the sea, the stability of the equilibrium of the sea, the manner of noticing in the theory of the ebb and flow the various circumstances, which, in a harbour, have an influence on the tides; and, lastly, making a comparison of the theory with observation, and arriving at the conclusion, that the principal phenomena of the tides are in accordance with the theory of universal gravity.

The subject of his fifth book, which completes the *First Part* of

* Bowditch's La Place, Vol. II. p. 486.

the entire work, is, the Motions of the heavenly bodies about their own centres of gravity; under which head the author considers, in detail, the motions of the Earth, the Moon, and Saturn's Rings, about their respective centres.

In the *Second Part* of the work (which begins with the third volume, containing the sixth and seventh books), the author discusses the theory of the Planetary Motions, and their inequalities and perturbations, arising from all the known causes; beginning with the planet Mercury, and proceeding, in order, to the outer boundary of our system; excepting, however, the four newly discovered planets, Ceres, Pallas, Vesta, and Juno; the inequalities of which, as Dr. Bowditch observes, will not probably be completely ascertained for a long time.* In connexion with this part of his subject, La Place also considers the *masses* of the planets and of the moon; the determination of which, as he observes, is one of the most important objects in their theory.† This portion of the work concludes with important considerations on the formation of astronomical tables, and on the invariable plane of the planetary system and the action of the fixed stars upon the system; the great distance of which last, as the author observes, renders that action insensible.‡

After the theories of the planets themselves, the author gives that of their respective Satellites; beginning with the Moon, which occupies a large space (about half of the third volume), and which, as he remarks, has difficulties peculiar to itself, arising from the magnitude of its numerous inequalities, and from the slow convergency of the series by which they are determined. These inequalities, which arise partly from the oblateness of the Earth and Moon, and

* Bowditch's La Place, Vol. III. p. 187, note.

† Ibid, p. 333.

‡ Ibid, p. 343.

in part depend upon the action of the planets, are then discussed in order, and a comparison made of the theory with observation; to which the author adds the very interesting and delicate investigation of the secular variations, in the motions of the Moon and Earth, which may be produced by the resistance of an *ethereal fluid* surrounding the Sun; the existence of such a fluid being assumed by La Place as *possible.* Dr. Bowditch adds, in a note, that the existence of such a resisting medium is now considered highly *probable,* in consequence of the observed decrease of the times of revolution of Encke's comet, in its successive appearances between the years 1786 and 1829; and he further observes, that the extreme rarity of the mass of this comet, makes it peculiarly well adapted to the discovery of the effect of such a resisting ethereal fluid, which cannot, however, produce any sensible effect on the large and dense bodies of the planets and satellites.*

In the eighth book, with which the fourth volume opens, La Place considers the perturbations of the *Satellites* of Jupiter, Saturn, and Uranus; the masses of the satellites, the oblateness of the planet Jupiter, and the eccentricities and inclinations of the orbits of the satellites. The phenomena of the Satellites are of great importance; for, as La Place observes, although they have been discovered only two centuries, and their eclipses have been observed but a century and a half, yet, during "this short interval, these bodies have presented to our view, by the rapidity of their revolutions, all those great changes which time produces with extreme slowness in the *planetary* orbits; the system of the satellites *being an image of that of the planets.*" †

He next gives the theory of Comets; their perturbations at a

* Bowditch's La Place, Vol. III. p. 678.

† Mécanique Céleste, Vol. IV. Preface.

small or great distance from the Sun, and when approaching so near to a planet as to have their orbits wholly changed; and, lastly, their masses, which, from the circumstance of their action upon the planets being insensible, must be "excessively small." In the case of one of them, the first comet of 1770, La Place observes, we are sure, that the mass is not "one *five-thousandth* part of that of the earth." He adds, as a result of his calculations, that this comet passed directly through the space where Jupiter and his satellites were then situated; and yet it does not appear, that the comet produced the slightest alteration in the motions of those bodies; and, he concludes, generally, that, if in the immensity of past ages some of the comets have encountered the planets and their satellites, which is very probable, it does not seem that the shock can have had much influence on their motions. But he remarks further, that, if a comet, with a mass equal to that of the Moon, should encounter the Moon or a satellite of Jupiter, there is not the least doubt, that it would render the orbit very eccentric.*

After thus investigating the phenomena of the different bodies composing our system, and other parts of the universe, La Place proceeds to a subject intimately connected with all of them, — the subject of Light, and the theory of Astronomical Refractions, which will be further noticed hereafter.

In a supplement to this tenth book, La Place, after referring to a preceding part of his work (where he had considered the phenomena arising from the refractive power exerted by bodies upon light) and stating that this force is the result of the attraction of their *particles*, remarks, that the *law* of this attraction cannot be determined by the phenomena, because the only condition required, is, that it must become insensible at sensible distances; and this is the only case

* Bowditch's La Place, Vol. IV. pp. 435 – 437.

in which *corpuscular attraction* has been submitted to an accurate analysis. He then adds, that he shall now lay before mathematicians another case, which is still more remarkable, from the variety and singularity of the phenomena depending upon it, and from its being susceptible of an equally accurate analysis; the case of *capillary attraction*, a singularly curious and interesting subject, the theory of which he first published in the year 1806. The effects of the *refractive* power, he observes, correspond to dynamics and the theory of projectiles; those of *capillary attraction* correspond to hydrostatics and the equilibrium of fluids, which are elevated or depressed, according to certain laws. A minute and profound investigation of these laws, concludes this second part of the work; which completes the author's system.

It will not be uninteresting to pause here a moment, and in imagination place ourselves at a height, from which the vast subject of La Place's labors ought to be surveyed. If, then, we concentrate our attention upon it, as an entire object, we perceive the powerful intellect of the author, grasping the general phenomena of the matter of the universe, from the whole mass down to the minute and invisible particles, which are the ultimate component parts of that mass; beginning with the laws of equilibrium and motion, generally, as applicable to all matter, solid and fluid; then proceeding, step by step, to the subdivisions, or parts of the whole, considered as systems of bodies; and, next, to the individual bodies that are members of those systems; then, considering the laws of gravitation, and the mutual attraction and perturbations of the heavenly bodies; next, our own solar system, its planets, satellites, and comets; and, from the consideration of these, the author is led to the attraction of bodies of a particular character, that is, those which are homogeneous and of a spheroidal form, of which the Earth is an example, and is particularly discussed; and, connected with

which, is the figure of a fluid mass in equilibrium and having a rotatory motion, as the ocean of our Earth; and, finally, after considering the attraction between *masses* of matter, the author proceeds to that which takes place between their *particles.*

In this manner does the author bring into one grand and magnificent review, the wonderful phenomena of all matter, the entire mass of the material world, through the various portions into which it may be divided, till he arrives at those inconceivably minute particles, whose law of attraction cannot be certainly determined by the phenomena, because they elude the power of human observation.

Such is the outline of this extraordinary work; a work, which, an able writer observes, "does honor, not to the author only, but to the human race; and marks, undoubtedly, the highest point to which man has yet ascended, in the scale of intellectual attainment." *

The Translation and Commentary of Dr. Bowditch extend to the first *four* volumes of the original work; which, in fact, contain the whole of the author's plan and views of the Mechanism of the Heavens. La Place had, however, shortly before his death, added a fifth volume, which it is only necessary to mention very briefly at this time. It was published at an interval of twenty years after the former volumes, and contains historical notices of the labors of other geometers on the same subjects, together with such further researches, as the author himself had subsequently made. This volume has not been translated by Dr. Bowditch; but this was the less necessary, as he has incorporated into the notes of his four volumes, and under the proper heads, all the important scientific matter contained in this additional volume, except upon the subject of the Earth's temperature and the velocity of sound; so that the Translation

* Professor Playfair, in the Edinburgh Review, Vol. XI. p. 278.

and Commentary now furnish us, in English, with a complete body of astronomy, such as is not to be found in any other language.

The original work was the fruit of incessant meditation, upon the great subjects of it, for more than sixty years,* and under circumstances the most favorable, that could fall to the lot of man; the author having the entire command of his time, and being surrounded by all the scientific men of France, who could render him any aid in their respective departments. If an observation in astronomy was required, — if any experiment became necessary in meteorology, in chemistry, in mechanics, — if laborious calculations were wanted in mathematics, — in order to verify his theories, — the most eminent men of France, at the most advanced period of human knowledge, may be truly said to have been at his command; some of them, indeed, literally so, by orders of the government; and others, from that common zeal in the cause of science, which is always glowing in such a community.

And here, I cannot but ask you, for a moment, to compare with these highly favorable circumstances, the disadvantages, under which our lamented President intrepidly undertook the difficult and laborious task, which he has so successfully accomplished, and which has secured to him so honorable and enviable a rank among his eminent contemporaries of the scientific world. La Place, it is true, like him, in the earlier part of his life, had no family influence, or rank, to promote his advancement; he was the son of a farmer in Normandy. But here all resemblance in the circumstances of the two cases ends. For when La Place quitted his native province, and determined to make his own fortune, upon his arrival at Paris he presented himself to the celebrated D'Alembert, who was then at the height of his fame and influence in that capital. He addressed

* Fourier, Éloge de La Place, Mém. de l'Institut, Tom. X.

a letter to that eminent mathematician, upon the general principles of mechanics; the profound views developed in that communication could not fail to make a deep impression on so great a geometer; and what was the result? A few days afterwards, La Place was appointed professor of mathematics in the Military School at Paris. From that moment, says his distinguished eulogist, he was enabled to bestow his undivided attention on the science which he had chosen; and he gave to all his labors a fixed direction, from which he never deviated. This immovable and determined constancy in his views was always the principal characteristic of his genius; and he passed the whole of a long life (of seventy-eight years) in accomplishing his great design, with a perseverance of which the history of science does not, perhaps, offer another example.*

Contrast with this good fortune the situation, in which our President was placed from the earliest period of his life. Compelled, by his father's humble circumstances, when only ten years of age, to forego even the slender advantages of a common school, that he might by his personal services contribute to the support of the family; then placed as an apprentice in a ship-chandler's shop; and, at length, in order to gain a livelihood for himself, obliged to become a seaman, in his twenty-first year, and to continue in that occupation for a considerable period of his life, — what an example does his history present of the extraordinary results that may be obtained by talents and industry, under the most unpropitious circumstances! When he first started into manhood, the state of mathematical science in this country was extremely low; he found no competent judge to appreciate his attainments; no powerful patron, who could place him in a situation where, like La Place, he

* Éloge, par M. le Baron Fourier.

could give his undivided attention to his favorite science; nor was he, like that distinguished man, at once placed in comparatively affluent circumstances, and relieved from all solicitude for those necessary means of living, for which the student as well as the man of business must provide; but, on the contrary, obliged to maintain a constant struggle against the formidable obstacles I have mentioned, and with a slender physical constitution, that demanded incessant vigilance, lest its powers should be prostrated by the exertions of his ever active intellect; how much did he achieve within the term of a life, shorter by thirteen years than that of his great exemplar, and during which he could pursue the study of his favorite science only at those intervals of leisure, which the daily avocations of business allowed him.

It is under such circumstances, that we should compare the scientific labors of our President with those of the eminent men of other countries; and, especially, with those of the illustrious author, whose great work is the subject of the profound and lucid *Commentary*, of which I am now to give a brief account.

Here I may, in the first place, remark, that the mere mechanical bulk of Dr. Bowditch's work exhibits an amount of actual labor that astonishes us. The four volumes now completed contain nearly a thousand pages each; and Dr. Bowditch has given *three* pages of commentary for every *two* of the original; the text of which he has followed, volume by volume, to the end of the fourth, of which he had just strength enough remaining to revise the *thousandth* page a few days before his death.

The scientific men of Great Britain were astonished at his attempting what they justly called a "gigantic task," — the task of translating into our common language, and elucidating with a copious and able commentary, a work, which they acknowledge to be so profound, that there were hardly twelve persons in that kingdom,

who could even read it with any tolerable facility,* and not one who had then attempted to translate and explain it. Subsequently, indeed, to Dr. Bowditch's Translation being prepared for publication, there were printed in England two translations of the *first book* only, or about one third of the first volume, with notes, by Mr. Toplis, and by Dr. Young; but the latter extraordinary man, whom some of his countrymen place at the head both of "the letters and the science of England," left the eighth chapter of his translation, (upon the *Motion of Fluids,*) without any annotations, though it is the most difficult, and is one which Dr. Bowditch advises young students to pass over on their first reading of the work. Another translation, by Mr. Harte, was also begun about the same time; but no copy of it had been received in this part of our country, when Dr. Bowditch published his first volume.

An able English writer observes, that at the period of these publications there was a very meagre supply of works, in our language, illustrative of the celestial mechanism, "whether in the nature of express commentary and avowed illustration of the immortal work of La Place, or in the form of independent treatises, calculated to bring the whole subject before the reader in a more compendious and explanatory manner than was compatible with La Place's object."

The same writer, however, farther remarks, that these "desiderata" are now supplied; and "in a manner that leaves little to wish for"; and he adds, that, "if any thing were wanting to put our geometers effectually upon their mettle," it would be found in the extraordinary coincidence, that one of the works to supply the

* Quarterly Review, for July, 1832, Vol. XLVII. p. 558; and Edinburgh Review for January, 1808, Vol. XI. p. 281, in an article written by Professor Playfair.

want complained of is the production of "a *lady*, our own countrywoman," and the other, of an "*American*, by birth and residence." The writer then notices, in terms of high commendation, the first volume of Dr. Bowditch's La Place, and the "Mechanism of the Heavens," by the highly gifted female alluded to;* who, in that extraordinary work, has communicated the results of La Place's discoveries to the English nation, in their own language; and has thus repaid the obligation, which a century before had been conferred upon British science by a celebrated female mathematician of France; who, by her Translation of the *Principia* and her *Commentary* upon it, first made known to the French nation, in their native language, the great discoveries of Newton. †

Dr. Bowditch, having constantly in view *practical utility*, has in his first volume brought together various formulas which are of frequent use in the work and notes, and placed them at the end of his Introduction, for the convenience of reference. Of these he has given demonstrations at the end of the volume.

Another improvement, as it has heretofore been generally considered, is the introduction of *diagrams;* which students of this science find extremely convenient, though they have been discarded by mathematicians of great eminence. The use of them, to the extent allowed by Dr. Bowditch, is commended by a distinguished French mathematician, from whom Dr. Bowditch had received several letters respecting his work. ‡ Whether the practice has a tendency ultimately to retard or to facilitate the progress of the student, is not a question to be discussed on the present occasion.

In the Notes upon the Second Chapter of the First Book, which treats of the *Motion of a Pendulum*, Dr. Bowditch has done justice

* Mrs. Somerville. † See Note I, at the end.

‡ Letter from M. Lacroix to Dr. Bowditch, April 5th, 1830.

(as in numerous other instances) to that great French geometer, Le Gendre, by introducing the method of obtaining certain values by means of the Tables of Elliptical Integrals, computed by him. It has been a subject of regret, that, from any motives whatever, La Place should have omitted to do that justice himself to this distinguished mathematician.

On the other hand, the same spirit of justice, which influenced Dr. Bowditch in the case just mentioned, has led him in another part of the work (Book I. ch. 5) to vindicate the accuracy of La Place against the strictures of a writer in a celebrated European Journal, upon certain equations relating to the preservation of living forces and areas.

In another place, however, he finds La Place to have drawn too general a conclusion (ch. 7, on rotary motion), where he gives an equation which he says is integrable only in the three cases there specified by him; whereas Dr. Bowditch demonstrates, that there are three other cases not mentioned by La Place, in which this integration is possible by the same methods; and he then states them in detail.

In an elaborate Note on the First Chapter of the Second Book, Dr. Bowditch gives a very complete, though extremely condensed view of the subject of Conic Sections, and in so generalized a form as to comprehend them all within the compass of two pages.

The Fourth Chapter of the Second Book is upon the Computation of the Orbit of a Comet; and Dr. Bowditch, in his commentary upon it, when noticing Newton's Principia, remarks upon a fallacy which had run through all the editions he had seen of that work, and had even been defended by Newton's commentators as correct. This fallacy was noticed, many years ago, by Dr. Bowditch, in the Memoirs of the Academy, as I have before mentioned. *

* Bowditch's La Place, Vol. I. p. 460, note; Mem. Amer. Acad. Vol. IV. p. 62.

In the same chapter, he notices the method adopted by La Place, of combining the observations, with a view to the greatest accuracy in the theory of a comet; and he considers the method to be liable to some objections. He then, in a subsequent note, proposes a valuable improvement in the mode of correcting the elements by a method of his own. *

We have, in the same Book (ch. 6, § 49), an example of his own skill in finding the last terms of the series there in question, by an original method, which he had discovered and used before he had ever seen the work of La Place, where the same method is adopted.

In the subsequent chapter of the same Book, he considers the great and interesting question of the permanency of the Solar System, which La Place believed he had there fully established. Dr. Bowditch, however, found it necessary to make a very important limitation in La Place's celebrated equations of condition, from which that author had inferred, that the orbits of the planets will for ever remain nearly circular and in the same plane; and he then shows, that however just the inference may be, that the orbits of the three exterior planets, Jupiter, Saturn, and Uranus, can never be very eccentrical or deviate much from the same plane, yet it does not follow, from the same equations, that the orbits of the *smaller* planets will always be nearly circular and in the plane of the ecliptic; for the orbits of these might be very eccentric, and even parabolic, and the planes of them be perpendicular to each other, and yet the equation be satisfied. Dr. Bowditch had discussed this point many years before, and published a paper upon it in the Memoirs of the American Academy, which I have already mentioned. †

* Bowditch's La Place, Vol. I. pp. 463, 470.

† Mem. Amer. Acad. Vol. IV. p. 74.

The first volume of Dr. Bowditch's Commentary is concluded with a valuable summary of Spherical Trigonometry.

After this particular account of the first volume of this great work, I shall notice very briefly only a few of the more important additions of Dr. Bowditch to the succeeding volumes.

In a note on the Third Book (Chap. 1, § 3) he mentions, in passing, an important improvement he had made in a particular notation, and which he had adopted, in his Commentary on La Place, many years previously to the publication of a method used by an eminent French mathematician*, which is substantially like that of Dr. Bowditch, and is now in general use.

He next notices (in Book III. ch. 2, § 8) La Place's remarkable omission of an important term in one of his formulas, as originally published; and, what will appear most surprising is, that this defect appears to have remained unnoticed by mathematicians for nearly half a century. A similar omission occurs afterwards (chap. 5, § 38), and both of these Dr. Bowditch has supplied in the text, as being essential to the formula. In his Note on the last-mentioned case, he has also given a method of his own for ascertaining the value of the radius vector of an ellipsoid, being more general than that of La Place, and the same which he had many years before published in the Academy's Memoirs.†

Dr. Bowditch had peculiar skill in bringing any proposed formula to the test by means of extremely neat and simple cases. Of this there is a striking example in this second volume;‡ in which he shows by this test, that a rule proposed by an eminent English mathematician § is defective. I have understood, that Dr. Bowditch sometimes, among his intimate friends, alluded to this case as one of

* Baron Fourier, Secretary of the Institute of France.

† Vol. IV. p. 45. ‡ P. 207. § Mr. Ivory.

his most successful instances of this description. It arose from the following circumstance.

In the Philosophical Transactions of the Royal Society of London, for the year 1824, the able mathematician just mentioned published a paper, in which the principles used by La Place (Book III. ch. 3, § 18) in finding the equilibrium of a fluid mass were objected to as incomplete. Dr. Bowditch, in order to enable his readers "to judge of the difficulties of the subject, and of the sufficiency of the commonly received laws of equilibrium," gives a concise historical account of the different methods used from the time of Newton to the present day. After stating in his lucid manner the principles in question, he adds, that they "seem plain and satisfactory, and they were used by mathematicians during nearly a century, without any objection being made to them; and there was no doubt, in the mind of any one, that they comprised all the conditions necessary to the equilibrium of a fluid."

But in the paper abovementioned Mr. Ivory proposes another condition; which need not, however, be here stated.

This led to a reëxamination of the subject; and among the numerous opponents of Mr. Ivory's opinion was the celebrated French mathematician, M. Poisson; who, as Dr. Bowditch observes, points out several examples, in which Mr. Ivory's new principle, carried to its full extent, would lead to an erroneous result. To these examples Dr. Bowditch adds only one of his own (above alluded to), which he calls "an extremely simple case"; but that simple case decides the fate of the proposed rule.

In a subsequent part of this second volume (Book III. ch. 5, § 42) Dr. Bowditch notices an error in the computation of the figure of the earth, as deduced from the observed lengths of a pendulum in different latitudes; and he points out here, as he had done many years before in the Academy's Memoirs, the probable

source of the error committed by La Place in this instance; as he also does, a few pages afterwards, another error "of considerable importance," (to use his own words,) in a subsequent part of that author's calculation.

Now, in order to make this subject intelligible at least, if not interesting, I may be allowed to remind you, that there are four methods in general use for computing the oblateness of the earth, supposing it to be an ellipsoid of revolution; 1. By comparing the observed lengths of two consecutive degrees of the meridian. 2. By comparing the lengths of two degrees of the meridian measured in different latitudes. 3d. By means of the observed variations in the lengths of pendulums vibrating in a second of time in different latitudes. 4. By means of two equations in the moon's motion (the one in longitude, the other in latitude), depending on the oblateness of the earth.

The two former of these methods, though they would at first view seem to be the most natural and accurate, as being the application of actual admeasurement, are from various causes the most uncertain; the *fourth*, which results from the moon's motion, is almost wholly independent of any error arising from the inequalities of the earth's surface, and is the most satisfactory; and next to this is the third, founded on the observed length of the pendulum.

On this last method, Dr. Bowditch gives, in his Notes to this volume, a most useful investigation of the Earth's figure, from "the latest and best observations" of the pendulum in different parts of the globe. La Place, in his computation of the oblateness of the earth as deduced from the length of the pendulum, was obliged to use the ancient observations; and his results were, many years ago, shown by Dr. Bowditch to be incorrect. Since that time, numerous observations have been made, and with more accuracy, from the equator to Spitzbergen, within eleven degrees of the north pole;

and these have been brought together, and analyzed with vast labor, by Dr. Bowditch, from the Transactions of learned Societies, the works of individual authors, scientific journals, and every other accessible source of information within the range of modern science.

The result of this laborious investigation, however, is not absolutely decisive of the question. Dr. Bowditch remarks, that the observations, though made with the greatest care, differ so much from each other, that we cannot place great confidence in the result of any combination of them, unless the number of observations is very great; and it is, therefore, desirable to obtain many more than we now have, particularly near the equator, where the most remarkable variations have been found. But another remark made by him, on the result of the observations which we already possess, is singularly striking and interesting, as a proof of the minute exactness of modern science. He observes, that, instead of being dissatisfied with this result, we ought to feel some degree of surprise, that by means of the very small excess of the polar over the equatorial pendulum, which may be considered *as a base line of less than a quarter of an inch in length*, we can determine *within a fraction of a mile*, the difference between the polar and the equatorial radius of the earth. Dr. Bowditch adopts, as being very near to the true value, the ratio $\frac{1}{300}$, which he has always used, and which was proposed by La Lande, in his Astronomy, forty years ago.

This subject had been discussed by Dr. Bowditch more than twenty years previously, in a Memoir communicated to the Academy, to which I have already referred. The examination of the subject at that time was suggested by the republication of Rees's Cyclopædia in this country. In the thirteenth volume of that work, containing the article *Earth*, he found that the editor had published the "elegant method" of computing the oblateness of the earth by the observed lengths of pendulums in different latitudes, as it was

given by La Place in his *Mécanique Céleste*, but had allowed the application of the formulas to numbers to remain nearly as in the original work, — in which there was a material error, — and that additional mistakes had been committed by the author of the article itself. Dr. Bowditch justly observed, that as the Cyclopædia had an extensive circulation in this country, he thought it proper to notice these errors, in order that "currency might not be given to incorrect ideas on the subject"; and, as an additional reason, that by making the correction in question, we obtain from the observations of the pendulum a result much more conformable to those deduced from other methods. He then, in the same paper, points out the errors in the results, and their sources; to which I have already directed your attention.

The third volume of La Place's work contains, as before stated, the particular theories of the motions of the heavenly bodies; first giving the theory of the primary planets, and then that of their respective satellites; beginning with our own, the Moon, which occupies a large space. Dr. Bowditch's annotations on this volume are of the same important and useful character with those on the preceding parts of the work; but time will not permit me to refer to the different topics discussed by him. I may, however, be allowed to mention, that one interesting and important subject, which had previously come under his notice, is here more particularly considered; I mean, the effect produced upon the motions of the planets and their satellites by the resistance of an extremely rare ethereal fluid; to which I have before directed your attention, when noticing this part of the original work. Dr. Bowditch has also made a most valuable addition to this volume, — an Appendix containing a full view of the different modern improvements made in the modes of computing the orbit of a planet, or comet, moving in an ellipsis, parabola, or hyperbola; with the methods of computing

the place of the moving body at any time. This Appendix, as he observes in his advertisement to the volume, contains many important formulas and tables, which are useful to astronomers in making the computations just mentioned. Some of the Tables are new, and the others have been varied in their forms, to render them more simple in their uses and applications; none of them, he adds, have heretofore been published in this country; and several of the formulas have been introduced into the calculations of modern astronomy since the commencement of the first part of the original work. The Tables, as here given by Dr. Bowditch, are highly valued by astronomers for their convenience, beauty, and exactness.

The theory of *Comets* concludes the inquiries of La Place relative to the matter and form, and the motions, of the various masses or bodies, which constitute the system of the world. There remains, however, another subject, intimately and essentially connected with those inquiries, — the subject of *Light* and the Theory of astronomical Refractions, — which the author then proceeds to examine.

The motion of light in the mediums through which it passes, particularly in the atmosphere, is, as he observes, one of the most important objects of astronomy; whether we consider it in relation to theory, or to its effect upon every astronomical observation. We view the heavenly bodies through a transparent medium, which by inflecting their rays changes their apparent position, and makes them appear in different places from those which they really occupy; it is, therefore, important to determine the law of this inflection, so as to obtain the real situations of those bodies.* This investigation is accordingly pursued in the Tenth Book. The author adopts the Newtonian hypothesis of the *emission* of light; which, however, has been much shaken by more recent observations tending to confirm the undulatory or wave theory.

* Bowditch's La Place. Vol. IV. p. 438.

On either hypothesis it becomes essential to ascertain the laws of light. La Place, as before observed, pursues his investigation of the laws of reflection and refraction upon the *Newtonian* theory; and Dr. Bowditch, in an able and copious Note, shows how the same results may be obtained according to the wave theory.

But of the numberless topics of interest and importance discussed in this great work, none is more singularly curious than one, whose name will hardly convey a just idea of the subject itself, — I mean that of *Capillary Attraction*, which La Place himself pronounces to be "one of the most curious objects of Physics." * This is a part of the work, on which our late President has concentrated his powers of analysis with as much force and skill, as upon any of the numerous subjects which he has examined in his Commentary.

In order that the importance of this subject may be understood, and that a just view may be taken of the extent of it in its various relations, we must reflect for a moment upon some of the numerous modes, in which this species of attraction exhibits itself.

The most usual form, in which it has been the subject of observation and experiment, is, in the ascent of water, or any other fluid, in *capillary* tubes, or between two plates of glass placed near each other in a vessel containing the fluid. The same principle, however, governs the movements of fluids in numberless other cases; some of which are so familiar to us, that they cease to attract our notice. For example; when we fill a glass or other vessel with water, if the vessel is already wet, the water will be drawn upwards round the sides of the vessel, and present a *concave* surface; but if, on the contrary, the vessel is entirely dry, the water will rise in it with a *convex* surface, and may, in popular language, be heaped up even above the brim of the vessel. From the same cause, a light body

* Bowditch's La Place, Vol. IV. p. 694.

floating on the water near the side of the vessel, will suddenly be drawn into contact with it; and two bodies lying on the surface, upon being brought towards each other, will suddenly rush together. In the same way, too, we see the rain forming itself into pellucid drops, and hanging from the under surfaces of bodies, or standing in imperfect globules on their upper surfaces; and the same principle manifests itself in the form of

> "the dew-drops, which the sun
> Impearls on every leaf and every flower;

and in

> "the gentle tear let fall
> From crystal sluce."*

In short, the phenomena of capillary attraction are so constantly manifesting themselves, and under such various circumstances, that they present to the philosophical observer questions of singular interest and extraordinary difficulty. These questions are most elaborately and profoundly investigated by La Place and his commentator.

Among other investigations of Dr. Bowditch in relation to this subject, I ought not to omit the fact, that he has most thoroughly examined and analyzed the very celebrated work of the present day called the *New Theory of Capillary Attraction*, by the eminent French mathematician, M. Poisson; and has shown, by numerous examples from M. Poisson's work, that, profound and acute as that author is, he has, under a different form of notation and with vast labor, only arrived at results which are either identical with those before obtained by La Place under his own form of notation, or which may be easily obtained from them; and that the supposed

* Milton, Parad. Lost.

discoveries announced in the *New Theory* have not in reality advanced this branch of science. This portion of Dr. Bowditch's work, when published, will, in the opinion of our mathematicians, attract the notice of men of science in Europe as strongly, perhaps, as any part of his labors.

When I briefly ask your attention to one or two results of this investigation, and their connexion, — not obvious at first view, — with other branches of science, it will not cause any emotion of surprise, that this curious subject should have so deeply engaged the attention of the author and his commentator.

From these investigations, says La Place, "we perceive the agreement which is found between the *capillary* phenomena and the results of the law of attraction of the *particles* of bodies, decreasing with extreme rapidity so as to become insensible at the least distances that are perceptible to our senses. This law of nature is the source of *chemical affinities;* like gravity, it is not arrested at the surfaces of bodies, but penetrates them, *acting beyond the point of contact, but at imperceptible distances.* Upon this depends the influence of *masses* in chemical phenomena, or the capacity for saturation, whose effects have been so beautifully developed by M. Berthollet. Thus two acids, acting upon the same base, are divided in proportion to their affinities with it; which would not take place if this affinity acted only when in contact; for then the most powerful acid would retain the whole base. The figure of the elementary particles, the heat, and other causes, being combined with this law, modify the effects of it. The discussion of these causes, and of the circumstances which develope them, is the most delicate part of Chemistry, and constitutes the philosophy of that science, making known to us as much as possible the intimate nature of the bodies, the law of the attractions of their particles, and that of the foreign attractions which operate upon them." La Place adds afterwards,

that, "at the surface of a fluid, the attraction of the particles, modified by the curvature of the surface and of the sides of the vessel which contains it, produces the capillary attraction; therefore these phenomena, and *all those which Chemistry* presents, correspond to one and the same law, of which now there can be no doubt.* The effects of the capillary action, then, being reduced to a mathematical theory, as the author further observes, "there is only wanting in this interesting branch of physical science a series of very accurate experiments, by means of which we may compare the results of the theory with nature." †

But I must desist from further noticing the subjects of this great work in detail, and confine myself to a few general remarks upon the invaluable labors of Dr. Bowditch; who, by his Translation, first made the work accessible to all who speak the English language, in every quarter of the globe, and has accompanied it with a *Commentary*, which will still farther disseminate the important discoveries and speculations contained in it, by rendering them intelligible and familiar to great numbers of zealous students, whose comparatively slight attainments would, without such aid, have for ever debarred them from all use of the work.

One of the first remarks suggested by an examination of the work of Dr. Bowditch is, that, although his able and copious Commentary takes the name and place of *Notes* upon the original work, yet it not only contains elucidations of his author's text, but includes a history of the progress of mathematical science, from the time of La Place's original publication, more than thirty years ago, to the present day.

Another valuable service rendered by Dr. Bowditch is the

* Bowditch's La Place, Vol. IV. p. 1006 – 1009.

† Ibid., Vol. IV. p. 1015.

awarding of justice to different writers, whose labors had been made to contribute to the perfecting of the *Mécanique Céleste*, but who are not referred to in that work; so that La Place appears himself to be the author of discoveries, which belong to others. His contemporaries in France complained, that he was not willing to be just either to them, or to his predecessors; that his great fault was, his not citing the authors to whom he was indebted; and that he permitted the discoveries of others to appear to the world as his own.

It is not for us to determine how far these complaints of his countrymen were well-founded; in such cases the motive, of which we have not here the means of judging, is essential in estimating the justness of the charge. In point of fact, however, Dr. Bowditch has, in his Commentary, traced to their proper authors various processes and formulas, which, in the text, are not referred to their original sources.

Among the many eminent men, whose claims Dr. Bowditch has been careful to bring distinctly into view, the most conspicuous is the illustrious Lagrange; who, from his extraordinary mathematical powers, was at sixteen years of age made professor of mathematics in the Royal School of Artillery at Turin, in which every one of his pupils was older than himself.* This great man's talents and character, on the whole, appear to have commanded more of Dr. Bowditch's profound respect and admiration, than those of any other individual, whose works were the subject of his studies. Of his eminent talents he remarks, that, "upon the death of Euler, *Lagrange* remained, undisputedly, the greatest mathematician then

* Delambre, Notice sur la Vie et les Ouvrages de M. Lagrange; Mém. de l'Institut, Tom. XIII. 2e Série, p. xxxiv.

living"; * and among those traits of his character, which called forth Dr. Bowditch's warmest admiration, was his inflexible sense of justice towards other men of science; for, as his eloquent eulogist says of him, "throughout his writings, whenever he adduces an important theorem, he gives due credit to the original author of it; and when he corrects the ideas of his predecessors or contemporaries, it is always done with that deference which is due to genius." †

Immediately upon the publication of the first volume of Dr. Bowditch's Translation and Commentary he received, from distinguished mathematicians and astronomers of England, France, Germany, and Italy, the most gratifying testimonials of the great service he had rendered to science, and of the ability which he had displayed throughout the work; and, if time would permit us to indulge ourselves in this honorable pride, it would be interesting to you to listen to them, as it has been gratifying to my own feelings to review them in the numerous letters on the files of his correspondence; ‡ but I must forbear asking your attention to any farther details on this occasion.

Such is the noble work accomplished by Dr. Bowditch, and on which his fame, as a man of science, is ultimately to rest; and, assuredly, the most lofty ambition could not desire a more solid and lasting monument; a monument, which will endure as long as there shall be left a remnant of the human race to contemplate the mighty fabric of those heavenly systems, whose structure and laws are inscribed upon it.

The scientific reputation of Dr. Bowditch had been so long

* North American Review, Vol. XX. p. 363.

† Delambre, Notice, etc., p. lxxxviii.

‡ See Note J, at the end.

established, that he had, for many years before his death, been a member of various foreign Academies of Sciences; and, but for his death, would, doubtless, have soon been admitted into the Royal Institute of France. *

I have thus endeavoured to give you a brief, but, I fear, a very imperfect sketch of the scientific character and works of our lamented President. The particulars of his private life have already been fully exhibited in the interesting publications before referred to, and it is only necessary on the present occasion to add a few general remarks upon that subject.

In social life Dr. Bowditch was distinguished for great integrity, extraordinary energy of character, and unremitting zeal and perseverance in whatever he undertook to accomplish. His manner was ardent, and indicative of that warm heart, which has now ceased to throb for those friends who enjoyed the happiness of his society. His deportment was, to an extraordinary degree, unaffected and simple; and, in the expression of his opinions, he had an unmeasured frankness, which a heartless age of artificial civility would hardly consent to rank among the virtues. His reverence for truth, and for probity of character, was as deep-rooted, as his indignation was inexorable on the discovery of fraud or duplicity.

With a strong intellect, which was never unemployed, and a sensitive moral principle always in full exercise in the community around him, he may be justly said to have had a long life, though he did not attain to what we usually call old age, having hardly reached the close of his sixty-fifth year; which, however, as we are informed, was a greater age than had fallen to the lot of any of his lineal ancestors for several generations.

The fatal termination of his last illness was not anticipated by

* See Note K, at the end.

the public, till a short time before his death. When apprized himself of the apprehensions of his friends, in the first instance, and, afterwards, of the opinion of his eminent medical attendant,* that his malady must soon terminate fatally, he received the notice without dismay. He expressed a wish, — and what parent could feel otherwise! — that he could have lived to see his younger children grown up and established in life; but at the same time, with a heart full of gratitude to a kind Providence that had crowned him with innumerable blessings in this life, he declared his entire resignation and his readiness to depart.

The short interval remaining was employed, while his strength permitted, in arranging his official and private affairs, and in receiving the last sad visits of his near friends and other persons, who had peculiar claims upon him; during all which, his usual cheerfulness did not forsake him. One of those interviews, of a most affecting character, was given by him to the present distinguished Head of the University, with whom he had been associated for many years as a member of the corporate body of that Institution; and one of no less interest took place only a few days before his death with our distinguished associate, the chief magistrate of this State; the particulars of which are already known to you.

During his illness, among other occupations, he continued to employ himself in correcting the sheets of the last volume of his great work; but the progress of his disease was so unremitting, that, — as had happened to one of his illustrious predecessors, Lagrange, in whose life Dr. Bowditch had himself not long before regretted the unfortunate occurrence, — he had not sufficient strength remaining to enable him to complete the final revision of the whole volume. When he had reached the *thousandth* page, on which

* Dr. James Jackson.

his feeble hand had just traced a few intelligible signs, the iron grasp of disease snatched his last occupation from him for ever. His strength gradually failed; his physical powers refused their office; but his living intellect still shone bright and unclouded; and, like the sun in the firmament, whose radiant orb he had so often watched in mid-ocean, from the splendor of its meridian beams to the softened lustre of its evening decline upon the waters of the fathomless deep, his serene and tranquil spirit gently sunk to repose, in cloudless majesty, upon the bosom of the ocean of eternity.

NOTES.

NOTE A. p. vii.

THE remark made at that period by the American publisher, in recommendation of his work, will not be uninteresting at this day in relation to Dr. Bowditch, who was then about twenty-four years of age. He says: —

"For several new Tables and Additions to this work, the Editor takes this public opportunity of returning his thanks to Mr. *Nathaniel Bowditch*, of Salem, Fellow of the American Academy of Arts and Sciences, whose acknowledged talents, both as a theoretical and practical navigator, reflect high honor on the nautical character of his country."

The publisher adds, that one of the *Notes* (on Table XIV. of that edition) "was furnished by Mr. *William Bowditch*," who was a brother of Dr. Bowditch, and distinguished also for his mathematical knowledge.

NOTE B. p. viii.

IN going through this examination Dr. Bowditch made the last figure exact to the nearest unit; and no less than *eight thousand* errors were discovered and corrected in the work of Moore, and above *two thousand* in the Requisite Tables; though of the latter Dr. Bowditch justly remarks, that most of the errors were in the last decimal place, and in many instances would but little affect the result of any *nautical* calculation. But, he adds, when it is considered, that most of the Tables are useful on other occasions where great accuracy is required, it will not be deemed a useless improvement to have corrected so great a number of small errors. — *Preface to Practical Navigator*, p. vi. edit. 1802.

NOTE C. p. ix.

THE following extract of a letter addressed to me, June 4th, 1838, by Mr. George W. Blunt, of New York (a son of the original publisher of Dr. Bowditch's Navigator), of whom I had made some inquiries respecting the history of the work, will be interesting to the American reader.

"The first edition of the American Practical Navigator was printed but not published in 1801. As soon as Mr. Blunt had printed the corrections and additions of Dr. Bowditch he discharged all his hands, took the work, as far as printed, and a copy of *Hamilton Moore*, with all the errors marked, amounting to several thousand, and went to England. On his arrival there, he called on the publishers of Hamilton Moore, John and James Hardy, and Steele; was introduced, and, after some conversation, one of the Messrs. Hardy observed, — 'You have done us up in America with one of our best books.' On being asked what he meant, he replied, *Hamilton Moore.* Mr. Blunt then said, that was his business in England; showed them the copy of *Moore*, with the errors in it, and finally sold the printed copy of *Bowditch* on condition, that the *American* edition should not be sold until June 1802, to give them an opportunity to get theirs into the English market at the same time."

The *London* edition was announced (on its title-page) as "originally written and calculated by *Nathaniel Bowditch*, Fellow of the American Academy of Arts and Sciences; revised, re-calculated, and newly arranged, by *Thomas Kirby*, Teacher of the Mathematics and Nautical Astronomy." In the prefatory Address of the English publishers, who recommended their edition as an "Improvement" of Dr. Bowditch's work, they speak of having made an arrangement with Mr. Blunt, the American publisher; which they were induced to do, "not only by Mr. Bowditch's high reputation, but by reflecting upon the low state to which the existing Works on Practical Navigation had fallen in the opinion of men of discernment;" and add, that they had "spared no expense in securing to the British nation the benefits of American science and diligence."

Unfortunately, either the English editor, Mr. Kirby, or his printers, performed their duty in so careless a manner, that many errors were found in the *London* edition of Dr. Bowditch's work. This gave occasion to a British writer (Andrew Mackay, LL.D.) who published a rival work on

Navigation, to make Dr. Bowditch's supposed inaccuracies a particular object of attack. In criticizing his revision of Moore's work, Dr. Mackay says : — "In this last book, which is pretended to be very correct, are many errors and contradictions," and, "it would be a tedious task to enumerate the errors" contained in it. — *Pref.* p. xiv. 1st edit.

This charge was promptly and emphatically repelled by Dr. Bowditch in his next edition (1807), in which he says : — "A number of mistakes have been made in printing the Tables of Mr. Kirby's first (London) edition, some of which have been taken notice of by Dr. *Mackay*, in the preface to his Complete Navigator ; and, as the manner in which those mistakes are mentioned might lead the reader to suppose, that the same errors existed in the *American* Tables, it is thought proper explicitly to state, that *not one* of the 'many errors and contradictions' Dr. Mackay has mentioned is to be found therein."

Dr. Bowditch then adds, in a spirit of candor which his rivals and adversaries would have done well to imitate : — "It is so difficult to obtain perfect accuracy in a table depending solely on observations, that no one ever published was perhaps entirely free from error. As a proof of this assertion, we may refer to the Table published in London, in 1802, by order of the Commissioners of Longitude, in the third edition of the *Requisite Tables ;* which Table is esteemed as accurate as any published ; for in it the latitude of Sandy Hook is nearly four degrees too much, and that of Barbuda nearly fifteen miles too much, the last error being common to almost all books and charts. . . . . If farther proof of the justness of the remark, — that errors exist in all tables of latitudes and longitudes, — were wanting, it might be obtained by inspecting the Table published at London, in 1804, in *The Complete Navigator* by Dr. Mackay, in which are many similar errors ; three of which only will be mentioned, viz. Cape Ann Lights are laid down eleven miles too far to the northward, and are placed several miles to the westward of Salem instead of the eastward ; Barbuda is placed fifteen miles too far to the northward, and Atwood's Keys nearly a hundred miles too far south ; so that the remark made by Dr. Mackay, in the preface to his work, 'that the case of the seaman who has to trust to such tables is truly lamentable,' might in many instances apply with equal justice to his own table. The object in view, in pointing out these errors, is, to impress on the mind of the reader the utter impossibility of obtaining a perfectly

accurate table, and to induce him to exercise a spirit of candor in judging of errors that may possibly exist in this part of the work."

After this full denial of the charges brought against the accuracy of the *American* Practical Navigator, it was to have been expected, that Dr. Mackay would have the candor to make some acknowledgment on the subject. He, however, suffered his remarks to be repeated, in the second edition of his work, which was not published till three years after Dr. Bowditch denied the truth of his charges.

I may here add, upon the authority of the publisher of Dr. Bowditch's Navigator, that American shipmasters are continually applied to, in foreign countries, to sell their copies of the work, and that "foreign mariners arriving in the United States, of every nation, whether speaking the language or not, always want *Bowditch*, as it is commonly called; and wherever it has been used, it has always been preferred;" and no other works on Navigation "are equal to Bowditch in extent of utility, accuracy, and simplicity." A late English Journal, of established reputation, states, that Bowditch's Practical Navigator "goes, both in American and British craft, over every sea of the globe, and is probably the best work of the sort ever published." — *London Athenæum*, of April 28th, 1838.

NOTE D. p. x.

Of the minor improvements one may be here mentioned, which, though apparently trifling, is practically of considerable value to those who are in the daily habit of using the Tables, and whose calculations, at sea, must sometimes be prompt as well as accurate; and I mention this, not so much for its own importance, independently of other considerations, as to show the unwearied pains taken by Dr. Bowditch to render every possible facility in matters of practical use. The little improvement I allude to is, that, instead of the English and American numerals of the present fashion, (in which the figures are all of the same length, and do not rise above or fall below the line in any instance,) he adopted figures of the older model, which is still followed by the French, and in which the eye is enabled to distinguish, at a glance, those figures that bear some resemblance to each other and are apt to be confounded, in the haste of taking them from the modern Tables.

NOTE E. pp. xi and xii.

THE circumstances under which Dr. Bowditch was first enabled to obtain a copy of Newton's Principia (at that time an extremely rare book in this country) will not be uninteresting, as connected with his life and studies.

Since the decease of Dr. Bowditch, I have been informed by my respected friend, Col. Benjamin Pickman, of Boston, (formerly of Salem,) that this copy of the *Principia* originally belonged to him; and that he presented it to Dr. Bowditch, as he believes, through the late Rev. Dr. Bentley, of Salem, from whom he had himself received it as a token of friendship, while a student at Harvard University, in which institution Dr. Bentley was then an instructer.

So far as important consequences may justly be said to flow from small causes, how important have been those arising from the preservation of this single volume in the library of an enlightened individual, whose own pursuits, however, lying in another direction, rendered it of little value, comparatively speaking, to himself, but gave him an opportunity, most gratifying to his well-known feelings, of placing it in the hands of Dr. Bowditch, who, above all men in the country, at that time, was the best qualified to make the study of it beneficial to the public. Dr. Bowditch sometimes alluded to this occurrence; and, on the occasion of presenting a copy of his Translation of La Place's work to a friend, who declined accepting it, because, from his slight acquaintance with the higher mathematics, it would be of no use to him personally, Dr. Bowditch delicately insisted upon his taking it; and, in the last resort, reminded his friend, that, if it should not be of any use to him, personally, it might, perhaps, be placed in the hands of some one, to whom it might prove valuable, as the copy of the *Principia* had been to himself.

In connexion with Dr. Bowditch's early studies, the origin of the Library to which I have referred (p. xii.), and which had so important an influence upon his scientific acquirements, will, in many respects, be interesting; and I therefore subjoin the following account of it from Dr. Bowditch's last will, as published in Judge White's Eulogy:

"*Item.* It is well known, that the valuable scientific library of the celebrated Dr. Richard Kirwan was, during the Revolutionary war, captured in the British Channel, on its way to Ireland, by a Beverly privateer; and, that by the liberal and enlightened views of the owners of the vessels, the library thus captured was sold at a very low rate; and in this manner was laid the

foundation upon which have since been successively established the *Philosophical Library*, so called, and the present *Salem Athenæum*. Thus in early life I found near me a better collection of philosophical and scientific works than could be found in any other part of the United States nearer than Philadelphia. This inestimable advantage has made me deeply a debtor to the Salem Athenæum; and I do therefore give to that Institution the sum of one thousand dollars, the income thereof to be for ever applied to the promotion of its objects and the extension of its usefulness."

Judge White adds: — "I am happy to have it in my power to add, on the authority of the late venerable Dr. Prince, that the gentlemen into whose hands this collection of philosophical and scientific works had thus fallen (of whom he was one, and for many years after their librarian,) made an offer of remuneration to Dr. Kirwan, who respectfully declined it, expressing his satisfaction, that his valuable library had found so useful a destination."

NOTE F. p. xvi.

In order to give some idea of the labor expended on his calculations in this instance, it may be here mentioned, that the original *manuscript* volume upon this comet consists of 144 folio pages of figures, in his minute and close handwriting; while all that the public are acquainted with is the *results*, which he has compressed into *twelve* quarto pages of the printed Memoirs of the Academy. The following extract of a letter from him to the German astronomer, Baron Zach, in relation to this subject, will be interesting to the American reader. The letter is dated at Salem, the 22d of November, 1822, and is published in Baron Zach's *Correspondance Astronomique*, Vol. x. p. 223.

"In calculating the orbits of the comets of 1807 and 1815 [1811 ?], I made many unnecessary calculations, as you will see in my memoir; but it was an amusement to me, to see how near I could come to the true elements of those orbits by means of observations made only with a Reflecting Circle of Borda; and I had the satisfaction to find some of them agree perfectly with those which the best astronomers of Europe had ascertained."

Baron Zach, in a note, inserts the elements here mentioned, with the following remark: — "As the literary productions of America reach us very

late, and sometimes not at all, we here give the elements of the orbits of the comets, calculated by Mr. Bowditch, upon observations *entirely American*, made at Salem by Mr. Bowditch, at Nantucket by Mr. Folger, junior, at Cambridge by Mr. Farrar, at Falmouth by Mr. Nichols, and at New Haven by Mr. Fisher."

The learned editor also takes occasion to notice particularly Dr. Bowditch's constant attention to what would be *practically useful* in his researches; and refers with warm commendation to the sentiment expressed in the following passage of the letter just cited: — "You will see that I have studiously avoided all scientific parade, and have published the work [the Practical Navigator] according to the method of instruction used in our country, where we prefer, in these matters, *practice* to theory."

The difficulty of obtaining public patronage for any other works, than those which are obviously of *practical* value, especially for profound works of science, has been experienced in all countries. The following anecdote respecting the publication of Lagrange's immortal work, the *Mécanique Analytique*, affords an instance of this disheartening fact, even in Paris, the very centre of mathematical science. I am indebted for it, to an able article written by Dr. Bowditch for the North American Review.

"This work," says Dr. Bowditch, "was written at Berlin, but Lagrange wished to have it printed at *Paris*, where it could be executed in a better style. A copy was made and forwarded to the care of the Abbé Marie; and it would now hardly be believed, that he could not, in 1788, get a printer to undertake the publication of that single quarto volume, *without a guarantee to pay the expenses*, in case the sale of the work should not be sufficient. The Abbé agreed to this condition, and did even more; for, at his own expense, he procured the assistance of one of the first mathematicians of Paris, Legendre, to overlook the publication, and see that it was printed correctly. The second edition of this immortal work was published in 1811, with many additions and improvements, showing the vigor of his mind though in extreme old age. Unfortunately for science, he did not live to complete the whole of the second volume, and a few of the last chapters are given exactly as in the first edition." Dr. Bowditch adds, that "this work ought to be studied frequently by every one who wishes to learn the most approved methods of treating the science of Physical Astronomy. It is much easier to read than La Place's *Mécanique Céleste*, as it does not go into the detail and numerical

calculations, which are necessary in the application of the formulas." — *N. A. Review*, Vol. xx. p. 364. See also *Éloge de M. Lagrange*, in Mém. de l'Institut, Tom. xiii. p. lx. 1e Série.

NOTE G. p. xviii.

It will be perceived, that the observations of Dr. Bowditch upon the Variation of the Magnetic Needle were made thirty years ago; since which time far more extensive researches, than were then practicable, have been made in different parts of the United States, as well as in Europe, on this important subject. A highly valuable Table of Observations, made on the Variation and Dip of the Magnetic Needle in different parts of the United States, for more than a century past, has been lately published by Professor Loomis (of the Western Reserve College, State of Ohio), in the *American Journal of Science*. Professor Loomis urges upon men of science the great importance of observations of this kind "to a much greater extent than has been hitherto done;" and he states his conclusions, from the present data, as follows: —

"From an attentive examination of the preceding Table it will be seen, that, from the time of the earliest observations down to the commencement of the present century, the *westerly* variation was *decreasing*, and the easterly increasing in every part of the United States; that more recently, the reverse has taken place, that is, that a retrograde movement of the needle has commenced. The precise year when this change took place cannot be certainly known. To determine this, we need more numerous and more accurate observations. All the observations, however, agree in this, that the change began as early as 1819, while the Philadelphia observations would make it as early as 1793, and those at Newbern (North Carolina) not far from the same year. The annual motion is much greater in the eastern states than in the south and west. I have carefully compared all the observations contained in the preceding table, and, without giving the particulars of this discussion, will state at once the conclusion at which I have arrived, viz. that the *westerly variation is at present increasing and the easterly diminishing in every part of the United States;* that this change commenced between the years 1793 and 1819, probably not everywhere simultaneously; and that the

present annual change of variation is about 2′ in the Southern and Western States, from 3′ to 4′ in the Middle States, and from 5′ to 7′ in the New England States."

This interesting paper is accompanied with a valuable *Magnetic Chart of the United States*, constructed by Professor Loomis, which "is intended to represent all the observations contained in the preceding Table reduced to the present time." *

In *Europe* the great importance of this subject has lately induced the Government of Russia, "the classic soil of terrestrial magnetism," as its Academicians call it, to order Magnetic Observations to be made, in connexion with a general system of Meteorological Observations, throughout the Empire. Numerous little observatories have been established in various places, for the purpose of beginning a course of these observations. At St. Petersburgh a *pattern* observatory is established, in which a number of officers are qualified, by the necessary practical instruction for one and two years, to become observers in the small establishments of the interior. Each of these observers has two aids, who lodge in the observatory; a rigorous and uniform system is followed, in the distribution of the hours, the selection of instruments, and the methods of observing. Meteorological observations are made eight times a day, and, in certain designated places, the Variation and Dip of the magnetic needle are also noted at the same times; the Variation is further observed, at certain periods of the year, simultaneously with the observations made in other parts of Europe.

The first part of these official observations has been lately published, by the Russian Government, under the title of "Observations Météorologiques et Magnétiques, faites dans l'Empire de Russie, redigées et publiées aux Frais du Gouvernement, par A. T. Kupffer, Membre de l'Académie des Sciences de St. Petersbourg." 4to. pp. 90.

NOTE H. p. xxiv.

The following are all the reviews and smaller published works of Dr. Bowditch, that have come to my knowledge:

1. Notice of the Comet of 1807; published in the Monthly Anthology, Vol. iv. p. 653.

* Silliman's Journal of Science, Vol. xxxiv. p. 290; for July, 1838.

2. Review of a "Report of the Committee [of Congress] to whom was referred, on the 25th of January, 1810, the Memorial of William Lambert, accompanied with sundry Papers relating to the Establishment of a First Meridian for the United States, at the permanent Seat of their Government." Published in the Monthly Anthology, Vol. ix. p. 245.
3. Defence of the Review of Mr. Lambert's Memorial. Monthly Anthology, Vol. x. p. 40.
4. Review of Olbers's Treatise on the most easy and convenient Method of Computing the Path of a Comet; and Gauss's Theoria Motus Corporum Cœlestium in Sectionibus Conicis Solem ambientium, etc. (containing a brief account of the progress of astronomy in Germany. Published in the North American Review, Vol. x. p. 260.)
5. Letter to Baron Zach; published in his *Correspondance Astronomique*, Vol. x. p. 223, for the year 1824.
6. Review of particular Works of Bessel, Burckhardt, Bouvard, Delambre, Lindenau, and La Place, (comprising a view of Modern Astronomy, and an account of the most distinguished writers on the subject. Published in the North American Review, Vol. xx. p. 309.)

To these Reviews may be added a great number of articles published in the *Mathematical Diary*, a quarterly journal. I am informed, that he solved every question that was proposed in that journal; and his solutions, part of which only were published, were, as we should expect, distinguished for their elegance, simplicity, and precision.

☞ To the *Memoirs* by Dr. Bowditch, mentioned in the text, should be added the following, which were accidentally omitted:

On the Eclipse of the Sun of September 17th, 1811; with the Longitudes of several Places in this Country, deduced from Eclipses and Transits published in the Transactions of different learned Societies. (*Mem. Amer. Acad.* Vol. iii. p. 255.)

Estimate of the Height of the White Hills, in New Hampshire. (*Mem. Amer. Acad.* Vol. iii. p. 326.)

On the Occultation of *Spica* by the Moon, observed at Salem, February 5th, 1820. (*Mem. Amer. Acad.* Vol. iv. p. 306.)

NOTE I. p. xliv.

The writer of the article in the Quarterly Review, here quoted, speaks of Mrs. Somerville as an *English lady*. In a subsequent volume of that journal,

the reviewer says ; "The latter (Mrs. Somerville) we are obliged to confess, is *Scotch* by her birth, though we are very happy to claim her as one of the brightest ornaments of England." — *Quarterly Review*, Vol. li. p 68.

NOTE J. p. lviii.

The following extracts from a few of the letters received by Dr. Bowditch, on the publication of the first and other volumes of his *La Place*, will be read with interest.

From Sir John Herschel, March 8th, 1830.

"It is very gratifying to me to commence a scientific intercourse, which I have long desired, with the congratulations which the accomplishment of so great a work naturally calls for ; and I trust, that its reception by the public will be such (of which indeed there can be little doubt) as to encourage you to proceed to the publication of the succeeding volumes, and that you will be favored with health, strength, and leisure to enable you to complete the whole of this gigantic task in the masterly manner in which you have commenced it. It is a work, indeed, of which your nation may well be proud, as demonstrating, that the spirit of energy and enterprise which forms the distinguishing feature of its character, is carried into the regions of science ; and every expectation of future success may be justified from such beginnings."

From Charles Babbage, Esq., Aug. 5th, 1832.

"It is a proud circumstance for America, that she has preceded her parent country in such an undertaking ; and we in England must be content, that our language is made the vehicle of the sublimest portion of human knowledge, and be grateful to you for rendering it more accessible."

Dr. Bowditch also received letters from Professor Airy, Francis Baily, Esq., the Bishop of Cloyne, (Brinkley,) and other persons of scientific eminence in various parts of Great Britain, testifying, in the warmest terms, their great satisfaction at the masterly manner in which the work was executed, and their high sense of the valuable service rendered by Dr. Bowditch, in giving to England and America his Translation and Commentary in the common language of the two countries.

From *France*, he received many letters of the same character; of which I can notice but a few, containing particular remarks upon it.

Letter from M. Lacroix, Paris, April 5th, 1830.

"Your work, in the first place, is a good book on account of the numerous aids it affords for surmounting the difficulties that must be encountered in reading the original, in which La Place has passed over many of the intermediate and almost indispensable steps. Besides doing honor to the able, patient, and conscientious geometer, who has undertaken this great labor, your work, by the beauty of its typographical execution, does honor to the country where it is published. It is, perhaps, the most beautiful book that has appeared upon mathematics. The calculations in it possess the greatest neatness; and the figures, which you have inserted in the body of the work itself, unite the greatest elegance with convenience. An undertaking so remarkable entitles you to the gratitude of those who are desirous of studying, to the bottom, the theory of the system of the world which rests upon transcendental mechanics; and it makes us wish for the speedy publication of the remaining volumes."

In another letter, (July 1st, 1835,) M. Lacroix says: — "I am more and more astonished at your continued perseverance in a task so laborious and extensive. I perceive, that you do not confine yourself to the mere text of your author and to the elucidations which it requires; but you subjoin the parallel passages and subsequent remarks of those geometers who have treated of the same subjects; so that your work will embrace the actual state of science at the time of its publication." And in a previous letter, (January 18th, 1833,) the same distinguished mathematician says: — "I have already had occasion to recommend it to a young professor at Lausanne, who requested of me some explanations of the work of La Place."

Letter from M. Legendre, Paris, July 2d, 1832.

"Your work is not merely a *Translation with a Commentary;* I regard it as a new edition, augmented and improved, and such an one as might have come from the hands of the author himself, if he had consulted his true interest, that is, if he had been solicitously studious of being clear," &c.

Letter from M. Puissant to D. B. Warden, Esq. (by whom Dr. Bowditch's work was transmitted), dated May 31st, 1835.

"I have received through you the third volume of the beautiful and valuable Translation of the Mécanique Céleste of La Place, with which

your scientific countryman, Mr. Bowditch, has honored me. The numerous additions which accompany the text, and which, in their turn, deserve to be translated into French, are the more important, as they clear away the difficulties which the subject frequently presents, and moreover include whatever Mr. Bowditch and other geometers have added to the theory of the motions of the heavenly bodies."

His scientific correspondents in *Germany* were equally strong in their commendations of his work.

Mr. *Bessel*, at Königsberg, in a letter of February 18th, 1836, observes: — "Through your labors, on the *Mechanism of the Heavens*, La Place's work is brought down to our own time, as you add to it the result of the studies of geometricians since its first appearance. You yourself enrich this science by your own additions, for which special obligations are due to you."

Mr. *Encke*, at Berlin, in a letter of May 5th, 1836, characterizes the Translation as a work, "which, by the depth of the researches with which it is accompanied, will insure to you a distinguished place among the astronomers who have employed themselves on the difficult branch of Physical Astronomy."

The reception of the work by the practical astronomers of *Italy* has been not less gratifying. I will only add an extract or two from letters of Mr. *Niccolò Cacciatore*, Director of the Royal Observatory at Palermo.

In a letter of May 1st, 1836, he informs Dr. Bowditch, that he had been charged by the Royal Academy with the duty of making a report upon his work, which "had excited the enthusiasm of all who took an interest in the subject of it." And in a letter of the same date, addressed to one of his correspondents in the United States, he expresses himself in the following strong language: — "The work of Bowditch is great, very great. After having made my Report upon it to the Academy, which was very brief, because I was obliged to confine myself to narrow limits, I placed it on my study table, and now make the reading of it my pleasant employment. I find in it much to reflect upon, and much to learn. Bowditch has filled up, and in a superior manner, the design of the Mécanique Céleste, and has, moreover, corrected certain blemishes which have been noted in that work. Those comments and those notes, in my opinion, place Bowditch at the head of living mathematicians." In another letter to the same correspondent, of a later date, (September 21st, 1837,) Mr. Cacciatore says: — "In the enthusiasm of my admiration I have briefly

mentioned it [Bowditch's La Place] in my work on Goniometry, p. 56, as you will see. The three volumes, with which the distinguished author has complimented the Academy, make them ardently desirous of seeing the fourth volume, as well as the other works of the same author."

The passage of Mr. Cacciatore's work, here referred to by him respecting Dr. Bowditch, is as follows: —

"The profoundness and clearness, which are conspicuous in that work, demonstrate, that it was only by the aid of such powers of analysis, that a commentary could be written upon the immortal work of La Place, and that La Place cannot be read with advantage, unless it is accompanied with the Notes of Bowditch. Italy must have a translation of it." — *Esercizio di Goniometria, ecc., dal Cav. Niccolò Cacciatore, Direttore del Reale Osservatorio.* 8vo. Palermo, 1837.

NOTE K. p. lix.

Dr. Bowditch was a member of the following Scientific Societies; which are here placed in the order of the dates of his diplomas: — The Edinburgh Royal Society, January 26th, 1818; Royal Society of London, March 12th, 1818; Royal Irish Academy, March 16th, 1819; Royal Astronomical Society, London, April 13th, 1832; Royal Academy of Palermo, March 12th, 1835; British Association, June 29th, 1835; Royal Academy of Berlin, March . . . , 1836.

I have stated, that he would soon have been elected a member of the Royal Institute of France. An American gentleman who was in Paris, when the news of Dr. Bowditch's death arrived there, wrote to a friend in this country, under date of May 30th, 1838, as follows: — "Had he (Dr. Bowditch) lived a little time longer, he would have been a member of the Institute of France. His works had been referred to a committee; and, that committee having asked Mr. Warden to furnish such information as he possessed as to his various works, I was applied to, as likely to know much more than any one in Paris about them. I immediately sent to the committee a hasty sketch, containing such anecdotes as I had heard, and such facts as I knew; and was shortly after informed, that there was no doubt of his nomination and appointment. But within three weeks afterwards came the sad news of his death. . . . . I wish the Institute had moved a little earlier; for it would have been an honor to the country, and gratifying to him."
